Sustaining the Green Revolution by resource conserving technologies:

The Rice-Wheat Consortium's example

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The Indo-Gangetic Plains of Pakistan, India, Nepal and Bangladesh are endowed with plentiful natural resources, deep productive soils, sufficient good quality water, climatic conditions that permit multiple-cropping, high population densities and relatively good infrastructure. The Green Revolution (GR) of the 1970s and 1980s radically changed the traditional agricultural system of this region. Now, about 13.5 million hectares of land are in continuous rotation of irrigated rice and wheat, providing food and livelihoods for many millions. Between 1960 and 1995 rice yields increased from 1.55 to 2.66 tonnes/ha and wheat yields from 0.84 to 2.34 tonnes/ha.

The majority of the farm households have less than 5 ha of land, whilst a minority have more than 20 ha. All farmers use improved varieties of wheat with fertiliser. In rice, some farmers still grow traditional, fine quality varieties like *Basmati* as they fetch higher market prices. Mechanisation levels are high, especially in the western regions, with resource-poor farmers renting tractors and threshers for tilling and harvesting. Animal power is still common in the eastern regions, but farmers complain of the increasing costs of maintaining draught bullocks. Many farmers are moving to contract ploughing with tractors; dairy cows are acquired in place of draught bullocks.

Rice-wheat a safe system

The main factors for the initial success of the GR and the emergence of the rice-wheat system were the introduction of high-yielding, semi-dwarf varieties and chemical fertilisers. Pesticides, investments in irrigation infrastructure, political commitment and policy support played a lesser role. Free irrigation water, cheap agro-chemicals, subsidised power supply and low-interest farm credit were some of the crucial supports provided by South Asian governments that made intensive rice-wheat production profitable and a safe system for farmers.

Stagnation of production growth

However, in the past several years the productivity growth of wheat and rice has declined and the expansion of rice and wheat area has halted due to many reasons (Hobbs and Morris, 1996). Ecological degradation of the natural resource base has occurred as farmers using conventional technologies harvest up to 10 tonnes of cereal per year. Long-term rice-wheat experiments have shown that yield growth declines at constant input levels. Unbalanced use of fertiliser and delayed planting of crops are cited as major factors. Profitability has dropped as more inputs are needed to get the same yield. Input subsidies that favoured the GR have lacked farm-level incentives for efficient input use. The price of rice and wheat has declined steadily over the last 30 years. Partial removal of subsidies and ecological problems have put stress on the economy of farmers.

Ecological degradation

Resource degradation in the rice-wheat system can take many forms: loss of organic matter; mining of soil nutrients; build-up of weeds, diseases and pests; waterlogging, salinity and sodicity. Additional problems that reduce system productivity are: low nutrient and water use efficiency associated with delayed crop establishment, driven in turn by inappropriate tillage practices (delays in sowing wheat after rice can reduce yields as much as 1.5% per day); flat sowing and flood irrigation causing nutrient leaching; puddling leading to formation of a ploughpan, reduced soil permeability and enhanced soil cracking; and restriction of plant root and shoot growth and chlorosis due to temporary water stagnation. To compound these problems, *Phalaris minor*, the major weed in wheat has developed strong resistance to the commonly used herbicides and farmers have had to shift to new, more expensive herbicides. Excessive pumping from wells is leading to declining water tables in fresh water aquifer zones, while inadequate drainage is causing waterlogging and salinity in others. Many of these problems are interrelated and tend to be concentrated in areas where farmers practice continuous rice-wheat rotations (Pingali and Shah, 1999).

Rice at harvest time grown on beds in the Indian Punjab (9t/ha crop, 50% water savings)

Photo: Rice-Wheat Consortium

The Rice-Wheat Consortium

The concern today is to continue the GR sustainably – to make agricultural practices ecologically sound and more efficient while increasing productivity and profitability, improving farmer livelihoods and reducing poverty. As population in the region swells, a yearly cereal yield growth of about 2.5% will be needed to meet food demands. The Rice-Wheat Consortium for the Indo-Gangetic Plains (RWC) is an institutional mechanism created to deal with these issues in SE Asia. It is a partnership of national programmes (Bangladesh, India, Nepal and Pakistan), international centres (CIMMYT, IRRI, ICRISAT, IWMI and CIP) and various advanced institutions (Cornell, CABI Bioscience, IACR, Rothamstead, and IAC Wageningen etc.). The RWC believes that the key to a sustainable Green Revolution lies in Resource Conserving Technologies (RCTs).

Participatory research

A stakeholder participatory approach based on strong partnerships is being used to develop and promote new technologies. Stakeholders include researchers, extensionists, local manufacturers, NGOs and farmers. Farmers experimenting with technical options are proving more successful than researcher demonstrations of "finished" technologies. With access to the necessary equipment, farmers are adapting practices to their own situations and providing valuable feedback to the other stakeholders. This approach required a change in paradigm that increased the mobility of stakeholders, decentralised decision making and allowed for strong partnership and trust building. The long-term implications of farmer tested technologies on the environment are being closely monitored by a team of scientists.

Promising technologies

Promising technologies to ensure timely sowing and good plant stands, crucial for rice-wheat system productivity and efficiency, are being tested. RWC scientists have developed new tillage and other resource conserving options, such as surface seeding, zero / reduced tillage, bed planting, mechanical transplanting, laser levelling, dry seeding rice, etc. These options have opened up "space" (time, labour, land and water) for farmers to experiment with more diverse cropping systems.

Sowing wheat before harvesting rice

Surface sowing of wheat on to unploughed, wet soil before or after rice harvesting is working well in heavy, poorly drained soils. This technique is particularly relevant to farmers with small land holdings and little or no power sources. In the 1997-98 wheat season, farmers in Nepal using surface weeding were able to get their crop planted on time, despite continued rain, and harvested an average of 4 tonnes/ha. Farmers who used traditional methods were unable to plant a crop at all.

Zero tillage and stubble sowing

Zero tillage and sowing of wheat in standing rice stubble using a seed drill, locally manufactured in India and Pakistan, is a key technology for farmers with access to tractors. This drill, a modified version of the local *rabi* drill, costs US$400. Resource-poor farmers are able to rent them. In a variant of zero tillage (reduced or minimum tillage) a rotovator stirs a thin layer of soil in a strip ahead of the seed drill. Although it delays planting by 4-5 days compared to zero tillage, reduced tillage may be the preferred system for areas with post-rice harvest weed problems. There is also a "strip-till" version that cultivates only the area where the seed is placed and not the entire area. Both 2-wheel and 4-wheel versions are available for these reduced tillage systems. Such technologies open the door to improvements in resource efficiency leading to timely sowing, water savings, higher fertiliser efficiency, reduced weed germination, less herbicide use, reduced residue burning, lower fossil fuel use, decreased air pollution – and higher yields!

Farmers are very enthusiastic about the technologies as they save money and increase production. For example, current land preparation practices for wheat after rice requires nearly 12 tractor passes, whereas zero-tillage only one. This saves up to 100 litres of fuel per hectare, approximately 1 million litres of irrigation water and wear and tear of tractor parts. This is roughly a US$50-60 or 30% saving in production costs per hectare while increasing production simultaneously. The acreage of zero-till has risen from a few hectares in 1996 to 10,000 hectares in 1999 and over 100,000 hectares in 2000 in NW India and Pakistan. The main constraint now is the availability of sufficient good quality seed drills.

RWC scientists and farmers are trying to cut down on the burning of crop residues, which amounts to nearly 10 tonnes/ha. Leaving the stubble on the field as straw mulch and seeding wheat into this residue, rather than burning it, could improve soil structure and fertility, reduce water use and create a habitat for beneficial insects. This technology, however, is still in the experimental phase.

Broadcasting rice seedlings

Raising of seedlings in beds and transplanting them into puddled soil is the predominant method of cultivating rice. Puddling destroys the soil's physical properties and gets more expensive as real rural wages increase. Direct sowing has system benefits and is an attractive option when the problem of weed growth is tackled. Research is underway to find integrated ways to control these weeds. Broadcasting of rice seedlings, a system common in China, reduces labour even further.

Modified bed planter

Traditionally, wheat is planted by broadcasting on flat land. Research has proven that this method is not ideal for enabling uptake of nutrients and controlling of weeds. Bed planting was introduced by scientists as an alternative, and is being used by farmers in Mexico on about 0.5 million hectares of irrigated lands. Here, a machine makes two beds of about 70 cm width. The technology has interesting advantages: it saves seed rate by about 40-50 %; saves water by about 30-40 %; gives higher yields; reduces lodging; enhances mechanical weeding; overcomes temporary water logging problems; promotes rain water conservation and allows subsurface fertiliser placement for reducing N losses in rice and wheat.

The technology is mainly used in wheat, but is being adapted to rice. Costs of making the beds after every rice harvest is to be reduced by permanent beds on which each successive crop will be planted on the previous residue. Bed planting would enable crop diversification in rice-wheat areas with the introduction of soybean, maize, cotton, mungbean, vegetables, and canola on beds. It also has great potential for expanding the acreage of hybrids with reduced seed rate. The latest – modified – version called the PAU bed planter is manufactured locally in Amritsar, Punjab, India at a cost of about US$ 425 *ex-factory*.
A similar model is available in Pakistan.
To help make seed drills, hand tractors, and tractor implements more widely available, RWC staff are linking with and advising farmer groups, local machine shops, and agricultural engineering specialists.

Integrated Pest Management

To minimise the use of chemicals, the RWC is developing integrated control measures for pests, weeds, and diseases in the rice-wheat system. Planting wheat in beds facilitates mechanical weeding and provides good weed control without the use of herbicides. In farmer-participatory trials, zero-tillage reduced *Phalaris minor* populations by two-thirds in the first year. Growing early planting varieties (late October) means that the wheat crop is well established and can suppress *P. minor* as it emerges in mid-November. Crop diversification with sunflower, sugarcane and other crops helps reduce losses to weeds. Stemborers survive in rice crop residue, but zero tillage practices actually help reduce this problem by leaving the rice stubble standing or as a mulch, providing a habitat for beneficial insects that control stemborers.

Photo: Rice-Wheat Consortium

Pau bed planter for no-tillage wheat production

Integrated Nutrient Management

Balanced and efficient use of organic and inorganic fertilisers is crucial in making the rice-wheat system sustainable and profitable. The reduced use of cattle manure over the years has resulted in a decrease of soil organic matter. The use of zero-tillage and the halt to burning of crop residues will improve this situation. Soil organic matter dynamics are being studied and monitored in fields with new tillage options, rotations and crop technical innovations. The RWC is also working on on-farm development of Site-Specific Nutrient Management. SSNM builds on: 1) crop nutrient requirements based on economically efficient yield targets; 2) estimation of potential soil supply of N, P and K; and 3) plant N-status during critical periods of growth. The technique permits an estimation of leaf nitrogen content at specific stages in plant growth by measuring leaf greenness. This gives farmers an idea of when to apply fertiliser and in what quantities. Simple colour charts that help better targeting of fertiliser applications are being introduced to farmers. (Ladha et al. 2000).

Biotechnology will be needed

Further increasing the yield potential of rice and wheat seems inevitable. This can be done by using hybrids, synthetics or improving the photosynthetic efficiency of crops. While traditional plant breeding has been effective in improving crop yields, biotechnology can make this more effective, e.g., through marker assisted selection. Biotechnology can play a role in providing needed resistance for various pests, diseases and other biotic stresses. Herbicide resistant crops may finally enable farmers to use direct seeded rice without weed problems. Insect resistant crops could help reduce the application of pesticide sprays. A combination of biotechnology and resource conserving technologies may give the best perspective on continuing and sustaining the GR. Although investments in biotechnology are increasing fast, major benefits for the rice-wheat system are still to come. Of course, any research and release of genetically modified crops should adhere to biosafety and bioethics standards, and must be acceptable to civil society.

Policies needed

Policies concerning pricing, incentives, research, agricultural education, funding etc. are essential if the efficient use of inputs and RCTs are to be enhanced. The case of the Indian Punjab demonstrates how the efficient use of water is hampered when farmers are given water free of charge. Such a subsidy should be more production oriented and linked to water saving practices. The same applies to pricing of fertilisers and other inputs. Fertiliser subsidies could be easily used to regulate fertiliser application, to encourage the switch from prilled urea to urea super granule (USG) or slow release forms, and to promote machines that help deep placement of fertiliser to reduce ammonia volatilisation and nitrogen leaching. Easier credit to purchase equipment would certainly be a better policy than subsidies on equipment.

Making the shift to resource conservation

A major bottleneck in large-scale adoption of RCTs is the mindset of farmers and other stakeholders on, for example, the age-old practice of excessive tillage. The shift to RCTs requires a reorientation and retraining of all stakeholders. Integration of RCTs into the respective curricula will enable extension workers, scientists and farmers to learn the benefits and needs of these technologies. Public awareness on the benefits of RCTs at the farm, village, country and global level is needed. Reaching out to more farmers requires innovative ways of scaling up RCTs based on participatory approaches involving all stakeholders.

Can we make it?

Farmers who have experimented with these technologies show tremendous enthusiasm in adopting it and sharing it with fellow farmers. The RWC believes that these technologies will become common place in South Asia in the coming years. Similar successes of farmer led technology adoption are seen in Brazil and Argentina where conservation tillage has been adopted on millions of hectares of land.
However, one note of caution needs to be made. Unless the population growth in South Asia is reduced in the next 2 decades, it will not be possible to produce sufficient food without degrading the environment. ■

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Further information: www.rwc.cgiar.org/new

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Effective Micro-organisms Technology

EM-Technology was developed by professor Dr. Teruo Higa in 1980 at the University of Rhyukyus, Japan. At the First International Conference on Nature Farming held in Tahialand in 1989, the Asia Pacific Natural Agriculture Network (APNAN) was formed. This network established an international programme for promoting research, education and extension of nature farming with EM-Technology.

EM contains photosynthetic bacteria (*Rhodopseudomonas spp*.), lactic acid bacteria (*Lactobacillus spp*.), and yeast (*Saccharomyces spp*.). It also supports the activities of other microbes. It is claimed that EM promotes germination, growth, flowering, fruiting, and ripening in crop plants. It enhances the photosynthetic capacity of plants and the efficiency of organic matter as fertilisers. EM develops the resistance of plants to pests and diseases and suppresses soil borne pathogens and pests. It can also be used in human and animal health care. A good introduction on EM-Technology can be down loaded from www.agriton.nl/higa.html

In Pakistan EM-Technology is being promoted by Nature Farming Research & Development Foundation (NFRDF) which set up the Nature Farming Research Centre and the EM-Technology Training Institute. In the last 8 years extensive experimentation has led to some important innovations in EM-Technology. Now a wide network of EM suppliers and technology transfer officers are available for the thousands of farmers who have begun using EM-Technology.

In January 2000, the **EM World Journal** (ISSN: 1562-255X) was launched by Nature Farming Research & Development Foundation, 41-X-101, Susan Road, Madina Town, Faisalabad, 38060 Pakistan. Fax: +92 41 613507; nature@fsd.paknet.com.pk

The Journal contains research articles on EM-Technology in agriculture and health. One of the articles: **Technology of Effective Micro-organisms as an alternative for rice and wheat production** in Pakistan by Tahir Hussain et al., reports on a long-term field experiment at Faisalabad, Pakistan, to determine the agronomic and economic merits of EM-Technology. Results were, among others: EM applied in combination with NPK fertilisers, Green Manure (GM) and Farm Yard Manure (FYM) caused significant increase in grain and straw yield and in nutrient uptake by the grain and straw of each crop following the order NPK+EM > GM+EM > FYM+EM. The GM+EM treatment produced grain and straw yields of each crop that approached those for NPK alone. A comparative economic analysis of the treatments showed a significantly higher net return due to EM. The average net profit from rice and wheat production using EM was US$44.90 / ha and US$62.35 / ha , respectively, compared to about nil for the conventional rice-wheat system with optimal fertilisation and management.