Weeds, Rice and Poor People in South Asia

Rice farmers in South Asia are altering the way they manage weeds because of changes in the labour market and in cropping practices. Hand-weeding is being replaced by herbicides, and direct-seeding is being used to reduce water and labour costs associated with transplanting rice.

What are the implications for rice yields, for employment and for the environment? How can farmers learn to use herbicides wisely and safely? What pathways can be used to promote better weed management?

Two research projects in India and Bangladesh, supported by DFID's Crop Protection Programme are investigating these issues.

Weeds, Rice and Poor People in South Asia highlights key research findings, and explains how NGOs, government extension workers, and the private sector are working together to promote 'technology transfer' for safe sustainable weed management to large numbers of rice farmers.

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The Natural Resources Institute (NRI) of the University of Greenwich is an internationally recognized centre of expertise in research and consultancy in the environment and natural resources sector. The Institute carries out research and development and training to promote efficient management and use of renewable natural resources in support of sustainable livelihoods.

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Why we are helping farmers find cheaper ways to weed rice

The Green Revolution in South Asia has resulted in short, fertilizer-responsive modern varieties (MVs) covering almost 80% of the area planted to rice in India and Bangladesh. Rice production in both countries has risen almost threefold since the 1960s, outpacing population growth and triggering a fall in prices that has made rice cheaper for consumers.

Falling rice prices have benefited poor people, who spend about half their income on food. Twenty years ago, one day's wages for an agricultural labourer in Bangladesh bought 2.3 kg of rice. Today, one day's wages will buy 4.5 kg. Although the share of people living below the poverty line in South Asia has fallen since the 1980s, progress has been uneven. Meeting international targets for poverty reduction – halving the number living in poverty by 2015 – will continue to depend on growth in cereal production to keep food prices low.

As consumers, farmers have benefited by being more self-sufficient in rice, but as producers the price that they get for their product has fallen in real terms. At the same time, farmers' costs have increased, including labour costs. To escape this cost-price squeeze, farmers are searching for new ways to cut production costs, either by increasing yields, reducing input costs, or both. Tractors are replacing animal draught power for land preparation while machines are replacing human labour for harvesting and threshing. And – for better or worse – herbicides are continuing to replace the men, women and children who traditionally have hand-weeded Asia's rice fields.

Weeds are a major source of yield loss in rice. Other pests periodically cause severe losses, but yield losses from weeds are consistent, widespread and severe if not controlled. Farmers, therefore, invest heavily in weed management. Rice is usually hand-weeded two or three times. Weeding requires more labour than any other crop management activity. In India, estimates suggest that weeding requires 4 billion person-days of labour each year – equivalent to 4 days/year for every man, woman and child.

Once farmers learn to use herbicides effectively, labour costs can be halved with a change to direct-seeding rice instead of transplanting. Direct-seeded rice has largely replaced transplanted, irrigated rice in some areas of the Philippines, and large areas of Malaysia and Thailand, where herbicides have been widely adopted.

Policy issues

The rapid spread of herbicide use in rice raises four important policy issues.

Information flows

With market de-regulation, the private sector has become a key service-provider for agriculture. But suppliers often provide users only with information about their own products, concentrating on rates and the weeds killed rather than more comprehensive information on the costs and benefits of herbicides, and most critically, the integration of herbicide use with mechanical weeding and water management. Farmers need such information in order to make informed choices about whether, when and how to apply herbicides.

Manually weeding transplanted rice. Weeds are pushed into the soil, left on the bunds or fed to animals.

Human health, sustainability and the environment

Herbicides are generally less toxic than insecticides to both humans and the environment, but farmers need more information on how to use them wisely and safely. Inappropriate use of herbicides may produce resistance among weeds, with devastating effects on production costs and yields. In the 1990s, rice-wheat growers in India experienced an epidemic of *Phalaris minor,* an aggressive grass weed that had evolved resistance to the major herbicide applied in wheat. Providing information on herbicide choices will be essential to help rice farmers avoid a similar situation developing with weeds in rice.

Market failure

Market de-regulation, combined with failure to enforce quality standards and testing, has led to the adulteration of farm inputs like seeds, fertilizer and pesticides. Adulterated or poor quality inputs may be cheaper, but their ineffectiveness increases the risks of adoption for resource-poor farmers.

Poverty

Herbicides will reduce employment in agriculture for some of the world's poorest people, including women, who are replacing men in India's rice fields. Will the gains from herbicide use (reduced drudgery, timelier weed control, cash-savings for rice producers) outweigh the costs of reduced employment in crop agriculture? Can the rural non-farm sector provide alternative opportunities to earn income? To answer such questions, we must look beyond the use of herbicides by farmers and consider the costs and benefits of herbicides to society as a whole, including gender issues.

New challenges for rice researchers

Today, it is not enough to boost production and profits by encouraging farmers to simply grow MVs. Now researchers must also help them to grow rice more efficiently than before and with less impact on the environment.

Improving farmers' crop management means that farmers must know and understand much more about new rice technology than before. In place of 'top-down', blanket recommendations, farmers need to be given the information to make their own decisions. Research and extension systems are now evolving to include farmers as partners in the research and adoption process. By working closely with farmers, researchers can learn what information farmers need and how it can reach them most effectively.

The research challenge is particularly acute for two rice cropping systems in South Asia:

- the rice-wheat system of the Indo-Gangetic plains which occupies about 12 million ha – a high-potential, irrigated production system that supplies 40% of India's total food grain requirements
- the rainfed rice system that occupies 23 million ha and is a major source of income and food security for farmers and consumers in Bangladesh.

Differing methods of establishing a rice crop. From the left, transplanting, wet seeding and drill seeding, see Box 1.

BOX 1: Transplanting and Direct-seeding of Rice: Implications for Weed Management

Transplanting rice seedlings into standing water is a time-honoured way of rice culture. Standing water in a recently puddled field suppresses weed establishment and transplanting 10 to 20-day-old seedlings gives a major competitive advantage to the crop. Indeed farmers most likely originally adopted transplanting for the ready gains in managing weeds.

In recent decades, the need to increase productivity against the background of rising labour costs for transplanting has led to considerable increases in direct-seeding – particularly in South and South East Asia – and has become feasible because of short-season rice varieties, improvements in irrigation infrastructure, and the development of broad-spectrum, selective herbicides for weed control.

Direct-seeding of rice may refer to either wet or dry methods, being very different in the way the crop is established. Wet-seeding involves sowing pre-germinated seed (broadcast or mechanically seeded) on to puddled saturated (wet) soil and gradual flooding of the land. Dry-seeding involves shallow burial (drilled, dibbled or broadcast and covered) of seeds in dry soil. Dry-seeding methods are successful because they give flexibility where rainfall uncertainty is common. But both methods mean that weeds start growth at the same time as rice and result in very early competition for resources. Competitive grass weeds (such as *Echinochloa* spp.) are a particular problem.

Of all cultural factors affecting weed growth and development in rice, water is probably by far the most important. The presence or absence of water as well as the timing, duration and depth of flooding may switch the weed flora from exclusively aquatic species to entirely terrestrial species or a mixture of both. This means that farmers need to know how to manage water for effective weed control especially as some herbicides need to be applied to standing water, whereas others are most effective on saturated or moist soils. Where water regimes in the life of a crop vary due to topography, or timing due to water availability, different weed floras occur. ***Weed management in rice is becoming knowledge intensive.***

Two crop management innovations are particularly relevant: direct-seeding and improved weed management, including herbicides.

Direct-seeding rice instead of transplanting

Direct-seeding (Box 1) reduces costs because of lower labour requirements for crop establishment and reduced demand for irrigation water. By allowing earlier establishment and harvest of rice, delays in sowing the subsequent wheat crop can be reduced leading to higher yields in rice-wheat rotations. In rainfed systems, direct-seeding may allow farmers to plant additional crops after rice that use residual soil moisture. But direct-seeding also increases potential crop losses from weeds, and is only viable where farmers can use integrated weed management practices, including herbicides.

Improved weed management, including herbicides

Adoption of Green Revolution rice varieties and intensification has led to changes in weed management by increasing labour requirements and aggravating the prevalence of some problem weeds, increasing labour requirements, and intensifying seasonal labour bottlenecks due to synchronized cropping. Mechanized land preparation and MVs (which are short-strawed and so less competitive with weeds), have resulted in more frequent weeding in some areas. Farmers still rely chiefly on hand-weeding. Although herbicides are becoming more widely available, farmers commonly lack awareness and information about how to use them correctly.

The research projects

To capture livelihood gains from improved weed management, two projects were initiated to develop low-cost, labour-efficient methods of weed management for both direct-seeding and transplanting rice systems.

'Development of Weed Management Strategies for Rice-based Cropping Systems in Bangladesh' (Project 7471) conducted trials on-station and on farmers' fields in districts contrasting in production intensity. In Comilla district, where farmers grow two or three rice crops on the same land each year, research focused on weed management for transplanted rainfed *aman* rice (monsoon) and irrigated *boro* rice (post-monsoon). In Rajshahi district, where most farmers only grow a single transplanted *aman* rice crop, research focused on the possibility of direct-seeding early maturing rice with chemical weed control in order to increase the opportunities for planting a post-rice crop on residual moisture.

'Development of Sustainable Weed Management Systems in Direct-seeded, Irrigated Rice' (Project 7377) has conducted trials over 3 years on-station and in farmers' fields in Uttaranchal. These studies have identified weed management methods for direct-seeded rice as an alternative to transplanted rice. While direct-seeding reduces the labour and irrigation needed to establish the rice, limiting crop losses to weeds is a greater challenge for farmers. Alongside research on weed control, socio-economic and household studies have covered villages representative of the rural population and of the three agro-ecological zones (hills, Terai and plains) in the region.

What are we doing?

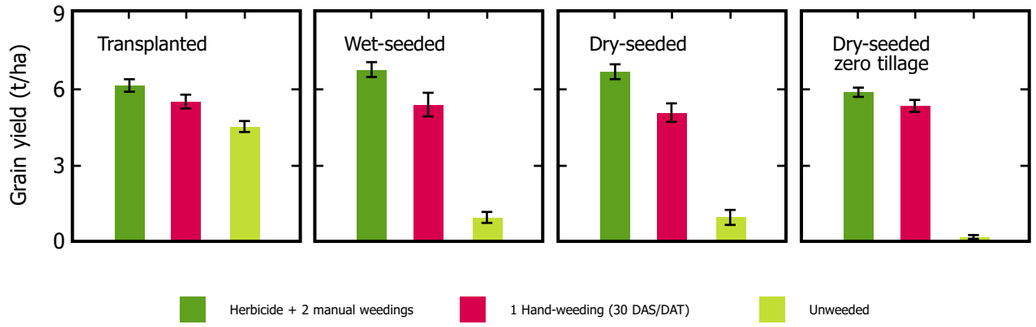
In India, trials on the research station have identified weed management options for wet and dry, direct-seeded rice. These studies have included land preparation, herbicide selection, timing and rates, monitoring of weed populations and initial selection of rice varieties with greater ability to compete with weeds. Farmers have been involved from the outset through on-farm trials where the best-bet management options have been tested, and wider exposure has been ensured through farmer field days, meetings and field visits.

In Bangladesh, on-farm studies have established the importance of weeds in terms of both the yield lost and inputs used for weed management. On-station and on-farm trials have identified weed management options for transplanted and direct-seeded rice. A detailed understanding of current approaches to water, weed management, farmer's perception of weeds, and post-rice crop decision-making has been built up through a series of participatory studies with farmers in a number of communities. In combination with the results from questionnaire surveys, this information has contributed to the selection of best-bet management practices evaluated initially with farmer groups. These are now being demonstrated and tested by farmers more widely through NGOs and the government Department of Agricultural Extension (DAE). The quickening pace of herbicide adoption has also been monitored to identify farmers' information needs.

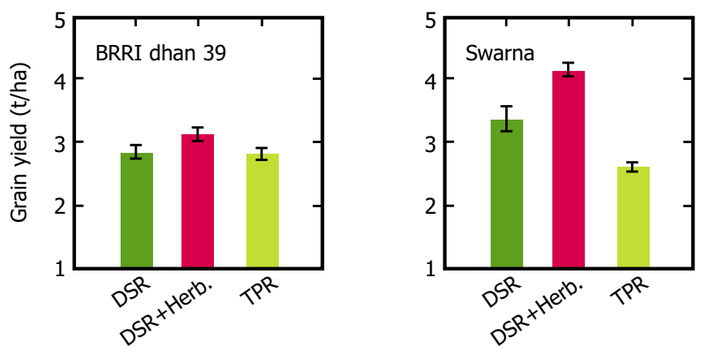
Who are we working with?

The International Rice Research Institute (IRRI) is a principal partner in both projects that have completed their research phase and are now moving towards promotional activities. Partnership with the Weed Ecology Working Group of IRRI's Irrigated Rice Research Consortium (funded by SDC) and the Rainfed Rice Research Consortium has strengthened capacity building in weed science in the region and links between national partners.

Figure 1. Comparison of rice yields from different crop establishment and weed management systems.

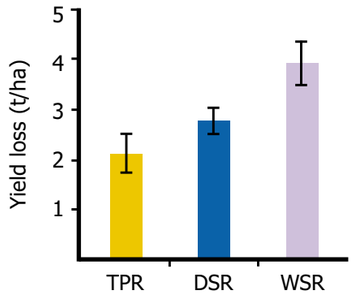


(a) Rice yields under different crop establishment methods in the irrigated rice-wheat system in India. Farmers can achieve equivalent yields to conventional transplanted rice by direct-seeding with savings in labour and water as indicated by benefit-cost ratios (excluding externalities) for transplanting of 1.96, 4.19 for wet-seeded and 5.6 for dry-seeded rice.



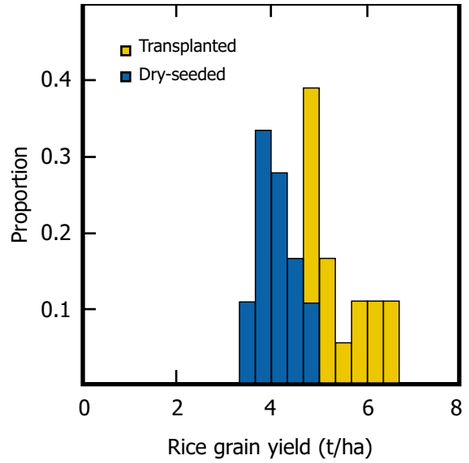
(b) Rice yields from rainfed lowlands of Bangladesh. Transplanted (TPR) and dry-seeded (DSR) rice achieved equivalent yields in the modern variety BRRI dhan 39 with hand-weeding, but superior yield in the local variety Swarna occurred with dry-seeding, yield being elevated further with the use of a pre-emergence herbicide (DSR+Herb).

Figure 2. Rice yield loss in the absence of weed control on farmers' fields in India.



TPR = transplanted
DSR = dry-seeded
WSR = wet-seeded

Figure 3. Variation in rice grain yields in on-farm trials in India.



India

Highly effective collaboration has been established with the Agricultural University at Pantnagar (GBPUAT), a benchmark site of the CIMMYT-IRRI Rice Wheat Consortium (RWC) and with staff in the conservation tillage project of the National Agricultural Technology Programme (NATP).

Bangladesh

Research is conducted through the Bangladesh Rice Research Institute (BRRI). In Rajshahi, field trials have been undertaken at a benchmark site of the IRRI co-ordinated Rainfed Lowland Rice Research Consortium (RLRRC, now CURE). The project is now collaborating with the DAE, the DFID-funded Plant Sciences Research Programme, and the local NGO Peoples' Resource Oriented Voluntary Organization (PROVA). In Comilla, the project is working with a local NGO, Sustainable Agriculture and Farming Enterprises (SAFE), DAE, and the agribusiness Syngenta to improve the information flow on weed management via the herbicide supply chain and by using a farmer field school approach.

What have we found?

Yields

In the rice-wheat system in India, rice yields in wet or dry-seeded crops have been higher than in transplanted crops (Figure 1), providing weeds are adequately controlled. With the savings in labour and water from direct-seeding, cost-benefit ratios are substantially improved. In direct-seeded crops, high yields depend to a greater extent on effective weed management, and Figure 2 shows the yield difference between good weed control on farmers' fields and where weeds had not been controlled. Yield losses from uncontrolled weed growth in wet-seeded rice can be particularly severe compared to transplanted crops. On farmers' fields, while yields in some cases have been comparable with transplanted crops, over 36 farms the yields were 20% less (Figure 3), often because of inadequate weed control. The change to direct-seeded rice had no discernible effect on wheat yields.

In Bangladesh, some 30% of farmers could save losses of 0.5 t/ha or more by investing in additional weeding in transplanted *aman* rice. In the irrigated *boro* rice crop, average yield loss due to weeds ranged from 0.2 to 0.7 t/ha depending on soil type. By contrast in the rainfed *aus* crop (pre-monsoon), yields are low and no significant difference has been observed between unweeded plots and those managed by farmers. However, additional weeding of farmers' fields gave an average yield increase of 1.1 t/ha.

Weed flora

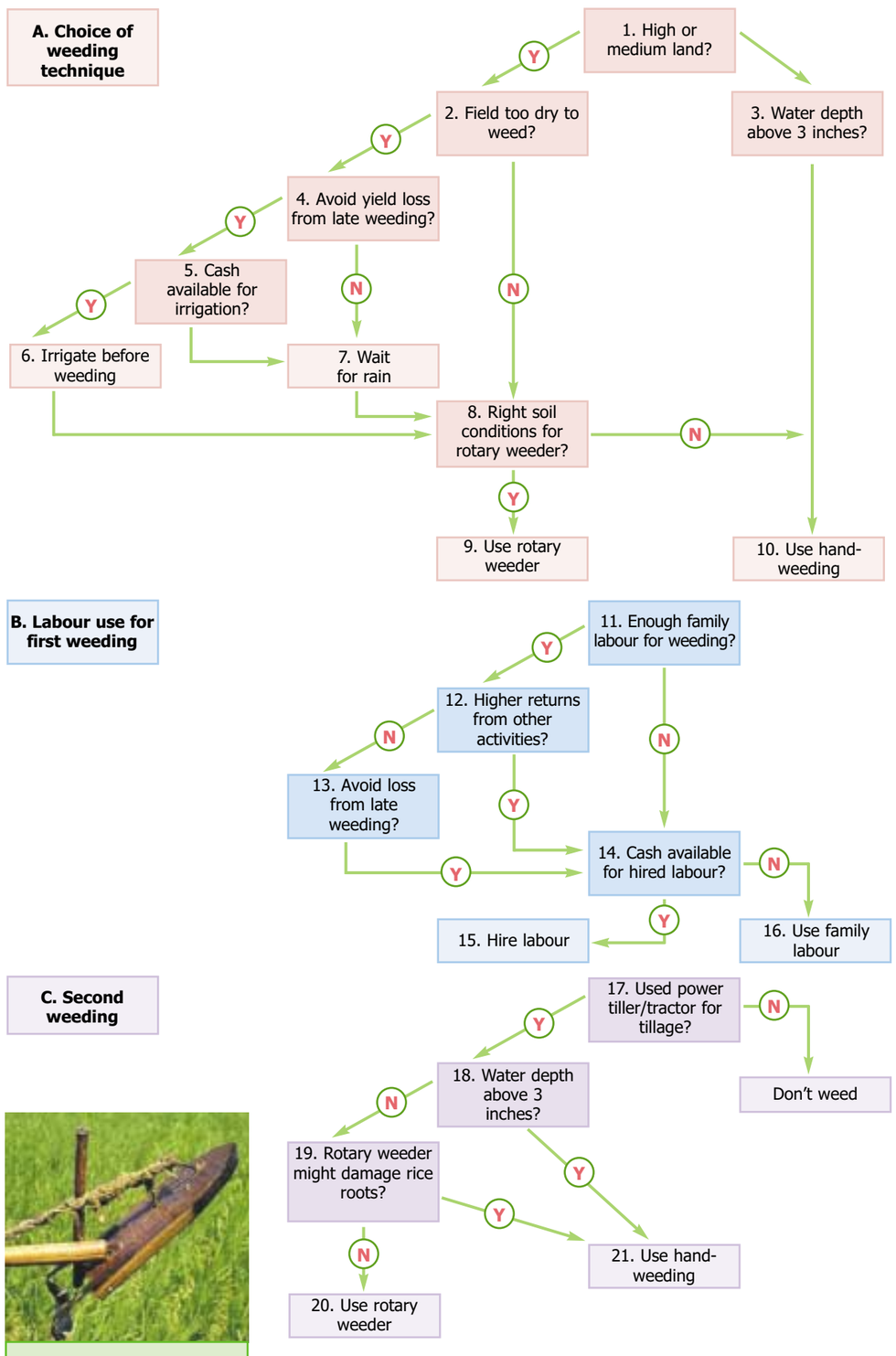
Direct-seeded systems face a potential threat from changes in the competing weed flora, with an increase in those species that are difficult to control. In both India and Bangladesh, these include *Ischaemum rugosum*, *Echinochloa crus-galli*, *E. colona*, *Leptochloa chinensis* and *Cyperus* spp. Changes in weed flora may require changes in weed management.

Weed management practices

Bangladesh

The timing of weeding *aman* (monsoon) rice varies widely between farms in Bangladesh. Weeding is later on larger farms that rely on hired labour, on sharecropped plots,

Figure 4. Decision tree for weeding transplanted *aman* rice, Comilla district, Bangladesh. Farmers in this district generally do not use herbicides; approximate times for first and second weeding are 28 and 56 days after transplanting.



Simple push weeder

and where productivity is generally low. Hence, there is great scope to improve the timeliness of weed management.

Farmers integrate a lot of information to decide when and how to weed. A decision-tree for weeding of *aman* rice showed that farmers in Comilla district did not use the rotary push weeder on softer soils, or where water depths exceeded 3 inches (Figure 4). Farmers in these circumstances have no option but to weed by hand.

Where poor water management for irrigated *boro* rice encouraged weed growth, the cost of labour for additional weeding was equivalent to one-third of the cost of irrigation. Herbicides can help reduce this cost but, to be effective, herbicides also need good water control in the early stage of crop establishment.

In Rajshahi district, the transplanted *aman* rice crop is still dominated by the local rice variety Swarna. Farmers also grow some MV rice, but this is harvested with Swarna, despite the earlier maturity of MVs. This is because farmers employ harvest labour gangs that harvest all rice at once on a contract basis. However, an increase in the area planted to direct-seeded, earlier maturing MVs which are harvested earlier could lead to increased production of dry season *rabi* crops.

Direct-seeding of rice under rainfed agriculture (Rajshahi) and transplanted *aman* or *boro* rice (Comilla) have produced similar yields in field trials with weeds managed by using a herbicide followed by one hand-weeding or by weeding twice by hand only.

India

Land preparation, transplanting and weeding accounted for the major share of material and labour costs in rice cultivation. Substantial savings could be made in the plains and Terai by introducing direct-seeded rice.

Most farmers in the plains and Terai already used herbicides for transplanted rice, but many complained herbicides were unreliable and only 50% effective. Farmers have very limited information on herbicides and commercial suppliers and fellow farmers were the major sources. Farmers are aware of weed resistance to herbicides and have countered this by experimenting with new products.

The overwhelming majority of farmers reported labour shortages for transplanting, for which they relied on hired labour. The village with the highest proportion of large farms employed migrant labour from as far afield as Bihar and Bangladesh.

A social cost-benefit analysis of herbicides/direct-seeding suggested that these technologies were socially profitable, despite displacing labour (Box 2).

Farmers with drilled, dry direct-seeded rice in India.

BOX 2: Who Gains? Who Loses?

Herbicides and direct-seeding may be profitable for farmers, but are they profitable for South Asia as a whole, where the livelihoods of many poor people depend on wages from employment in agriculture?

The answer will depend on the economic value of labour, which may be lower than its market value if there is widespread under-employment. In this case, economists evaluate the profitability of new technology using a 'shadow wage rate' which includes the cost to society of that under-employment. Where herbicides are concerned, it is also necessary for the evaluation to include the social cost of externalities such as damage to human health and the environment. Although we lack information on these costs, it is possible to ask:

- How much would labour wages have to fall (reflecting the economic value of labour) for the benefit-cost ratio of herbicides/direct-seeding to equal that of transplanting?
- How much would variable costs have to rise (reflecting externalities) for the benefit-cost ratio of herbicides/direct-seeding to equal that of transplanting?

A sensitivity analysis, based on data from experimental trials, answered these questions for Uttaranchal, India. Yields were held constant though, as we have seen, herbicides will improve average yields by reducing losses due to weeds. Results showed that herbicides/direct-seeding were as socially profitable as transplanting only if:

- labour was assumed to have no alternative use ('zero opportunity cost').
- environmental and health-related costs were twice as large as private costs.

In fact, the economic value of labour for peak season operations is probably near the market rate. In India, transplanting relies heavily on male labour that is highly mobile and wage-rates have risen in real terms through strikes and off-farm employment. In Bangladesh, the share of agricultural labourers in rural employment halved in the 1990s, as workers moved into higher-paying activities like transport, construction and agro-processing. ***Hence, rapid growth in off-farm employment would seem able to compensate for agricultural employment lost through herbicides and direct-seeding.***

How are we promoting the findings?

Both projects have now entered a dissemination phase. Research results are being promoted through a series of strategic partnerships. These involve not only the national extension service, but also local NGOs and the private sector.

Public-private partnerships

- In Comilla district, Bangladesh, researchers have joined SAFE and Syngenta to develop more effective extension methods for weed management, based on farmer field schools (Box 3).

National and university extension systems and national fora

- The DAE will also play a key role in exposing a large number of farmers to the opportunities afforded by chemical weed control in five areas of Comilla district, Bangladesh. Participating farmers will choose one practice to test from a menu of herbicide and mechanical weed control options that will be compared with their current method. These paired plots will provide sites for field days to be undertaken by village extension workers.
- In Rajshahi district, Bangladesh, researchers have linked up with the DFID-funded Plant Sciences Programme, the NGO PROVA and the national extension service to demonstrate *aman*-chickpea as an alternative cropping pattern to a single crop of transplanted rice. Demonstrations will be spread across 100 sites in Rajshahi, Chapai Nawabaganj and Noagaon districts and will include the use of a broadcast-applied, granular herbicide in both local and early maturing MV rice.
- In India, researchers are collaborating with extension workers to extend demonstrations of direct-seeded rice and appropriate weed management technology into new areas of the rice-wheat system in Bihar, Uttaranchal and Uttar Pradesh. Field activities are co-ordinated by the agricultural universities at Pantnagar, Patna and Faisabad. Other institutions involved include the Directorate for Cropping Systems Research (Indian Council for Agricultural Research, Modipuram) and the National Resource Centre for Weed Science, Jabalpur.

Conclusions

Weeds are an 'unfashionable' pest for researchers. Farmers know better. Weeds are a major source of yield loss in rice, and controlling weeds costs time and money.

Box 3: Improving Information Flow on Herbicide Use

Bangladesh – the world's fifth largest rice producer – is potentially a lucrative market for herbicides. Four agrochemical manufacturers dominate the herbicide market there, supplying products through a network of distributors and retailers, and promoting their products by village meetings, demonstration plots and field days.

As more farmers adopt herbicides, there is a need for a more comprehensive provision of information on both product and non-product specific issues, a process which will involve both private and public sector partnerships. A study of the herbicide supply chain in Comilla district revealed important knowledge gaps about yield losses from weeds, safety, water management after application, fate of herbicides in the soil, the potential for damage to the environment, and preventing the development of herbicide-resistant weed populations. Consequently, most farmers did not have enough information to make efficient decisions about weed management.

To improve the information flow, Syngenta and SAFE, a local NGO, are collaborating to produce training materials on better weed management, with technical support from researchers at NRI, IRRI and BRRI. This involves working with farmers in a participatory way to understand their information needs. SAFE has set up 10 farmer field schools (FFS), each with 20–25 farmers in Comilla district. Resource-poor farmers were selected through wealth ranking with the active involvement of village communities. Each FFS conducts field trials to evaluate different methods of weed management.

Stakeholders have formed a working group to co-ordinate their activities. A training workshop on 'Low-cost Weed Management Strategies in Rice Production' brought together FFS participants, pesticide dealers and extension personnel. This has laid the groundwork for an action-research programme until 2004.

SAFE's participation is funded by Poverty Alleviation Through Rice Research Assistance (PETRRA), supported by DFID, as part of a wider initiative by PETRRA to support innovative extension approaches. PETRRA expects that the partnership between SAFE and Syngenta will yield useful lessons about the potential for public-private partnerships in disseminating new technology to resource-poor farmers.

Better weed management would mean higher rice yields, more income for farmers, and would help sustain continued growth in rice production.

Better weed management raises important policy issues. De-regulation and market liberalization have helped farmers in South Asia to increase rice production. But market forces will not ensure sustainability, or quality controls, or reduce risks where farmers have imperfect information. Also, the introduction of direct-seeded rice and herbicides will reduce employment in agriculture. The social costs of the new technology in South Asia may not be prohibitive because non-farm employment is growing so rapidly. Nevertheless, these costs must be taken into account and may help justify other policy measures to protect vulnerable groups.

Better weed and crop management requires new extension approaches that provide farmers with the information they need to make their own decisions. Choices about whether to use herbicides, the timing of weeding, or water management for weeding are too complex for simple, prescriptive research recommendations. Hence, we need to improve the flow of information reaching farmers. The role of the private sector is critical here. Their marketing networks often reach farmers more effectively than state extension services. Working with the private sector, researchers can channel information to farmers that will improve their ability to manage weeds more effectively and safely.

Changing to direct-seeding saves time and water. S. Singh, Bajpur, India.

Research on weeds, rice and poor people is breaking new ground in helping policy-makers understand the issues at stake, and the role that applied research can play in giving rice farmers a more prosperous future.

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Copies of project Working Papers are available on request from Dr C. R. Riches, Sustainable Agriculture Group, Natural Resources Institute, University of Greenwich at Medway, Chatham Maritime, Kent ME4 4TB, United Kingdom.

Abbreviations and acronyms

BRRI	Bangladesh Rice Research Institute
CIMMYT	International Centre for the Improvement of Maize and Wheat (Mexico)
CPP	Crop Protection Programme (UK)
CURE	Consortium for Upland and Rainfed Environments
DAE	Department of Agricultural Extension (Bangladesh)
DFID	Department for International Development (UK)
FFS	farmer field school
GBPUAT	Agricultural University at Pantnagar (India)
IRRI	International Rice Research Institute (Philippines)
MV	modern variety
NATP	National Agricultural Technology Programme (India)
NGO	Non-Governmental Organization
NRI	Natural Resources Institute (UK)
PETRRA	Poverty Alleviation Through Rice Research Assistance (Bangladesh)
PROVA	Peoples' Resource Oriented Voluntary Organization (Bangladesh)
RLRRC	Rainfed Lowland Rice Research Consortium (IRRI)
RWC	Rice Wheat Consortium (India)
SAFE	Sustainable Agriculture and Farming Enterprises (Bangladesh)
SDC	Swiss Development Corporation