RIU

Low-tech plus high-tech for good upland rice

Validated RNRRS Output.

A novel combination of high-tech and low-tech approaches has successfully bred rice varieties for upland farms in eastern India. Farmers in Jharkhand, Orissa and West Bengal selected from among varieties whose roots had been improved by molecular breeding techniques. It's not possible to select for traits such as better rooting in farmers' fields, but combining laboratory methods and farmer selection works well. Nearly half the rice-growing area in the three eastern states is rain-fed upland. Here, as droughts are common, it's important for rice to send its roots deeply into the soil to get water. The new varieties reduce farmers' risks of losing crops or of poorer harvests because of lack of rain.

Project Ref: **PSP22:**
Topic: **1. Improving Farmers Livelihoods: Better Crops, Systems & Pest Management**
Lead Organisation: **CAZS-NR, UK**
Source: **Plant Sciences Programme**

Document Contents:

Description

PSP22

Research into Use
NR International
Park House
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Geographical regions included:

India,

Target Audiences for this content:

Crop farmers,

A. Description of the research output(s)

1. Working title of output or cluster of outputs.
In addition, you are free to suggest a shorter more imaginative working title/acronym of 20 words or less.

Molecular marker-assisted rice breeding

2. Name of relevant RNRRS Programme(s) commissioning supporting research and also indicate other funding sources, if applicable.

Plant Sciences Research Programme

3. Provide relevant R numbers (and/or programme development/dissemination reference numbers covering supporting research) along with the institutional partners (with individual contact persons (if appropriate)) involved in the project activities. As with the question above, this is primarily to allow for the legacy of the RNRRS to be acknowledged during the RiUP activities.

R6673, R7080, R7434, R7435, R8200, R8099

Partner Institutions	**Contact person(s)**
CAZS Natural Resources, University of Wales, Bangor, UK	Dr K.A. Steele Prof J.R. Witcombe Dr D.S. Virk
University of Agricultural Sciences (UAS), Bangalore, India	Dr H.E. Shashidhar
Gramin Vikas Trust (GVT) East, Ranchi, India	Mr V.K. Vij (Project Manager) Dr S.C. Prasad (Plant Breeder)
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4. Describe the RNRRS output or cluster of outputs being proposed and when was it produced? ***(max. 400 words)****. This requires a clear and concise description of the output(s) and the problem the output(s) aimed to address. Please incorporate and highlight (in bold) key words that would/could be used to select your output when held in a database.*

(1) Rice varieties are the main output. They are lines and bulks derived from **marker-assisted backcrossing (MABC)** between an adapted (recurrent) parent Kalinga III and a donor parent Azucena (Table 1). They contain chromosomal introgressions carrying **quantitative trait loci (QTL)** for improved roots that are transferred through **marker-assisted selection (MAS)**.

Focus group discussions and household level questionnaires have shown that farmers think that the MABC varieties are suitable for upland and medium land cultivation. They are likely to fetch higher market prices than existing upland varieties because of their slender grains. Thus the availability of these varieties will increase the options and opportunities available to resource-poor farmers. They are suited for use under direct seeding rice farming systems in rainfed upland and medium land ecosystems.

They have high levels of drought tolerance and lodging resistance. Some of them have an additional QTL for fragrance: a grain quality trait that increases the market value of the crop. To our knowledge, these are the first aromatic rices that are adapted to the drought-prone uplands of eastern India.

(2) Methods of effectively combining **MAS** with **COB** have been developed since 2000. These include combining marker-assisted selection for target **QTL** for root traits (including root length, thickness and penetration). These traits cannot be reliably selected for in the field even when using yield as an indicator so combining laboratory-based and participatory selection is an attractive method.

Problem addressed:
Rice is the major crop in the eastern Indian states (Jharkhand, Orissa and West Bengal states). About 46% of rice land is classified as rainfed upland where rice is grown by the small, resource-poor farmers (86 to 93% have < 2 ha land) who are primarily dependent on agriculture and migration. Low and erratic rainfall causes frequent droughts across this region. Frequently varieties released from national breeding programmes are not suited to these conditions so they are not adopted by farmers. These farmers continue to grow low-yielding old varieties or landraces (Witcombe et al., 1998; Virk and Witcombe 2006). Surveys have revealed that farmers in this region require varieties with early maturity, higher grain and fodder yield, good grain quality, drought tolerance, disease and lodging resistance in varieties.

Table 1. Rice lines and bulks from **marker-assisted backcrossing (MABC)** that are suitable for cultivation in upland and medium upland ecosystems in eastern India.

Output	**When produced**	**Origin of line**	**Target QTL**
Bulks with QTL			
Richa 1	2002	Selected from BC2F_2 (Bulk)	none (control)
Richa 2	2002	Selected from BC2F_2 (Bulk)	QTL7
Richa 3	2002	Selected from BC2F_2 (Bulk)	QTL9
Richa 4	2002	Selected from BC2F_2 (Bulk)	QTL11
Richa 5	2002	Selected from BC2F_2 (Bulk)	Aroma QTL and QTL 2, 7, 9, 11
Richa 6	2002	Selected from BC2F_2 (Bulk)	QTL2
Aromatic pure-lines selections from Richa 5 bulk			
P157	2003	line selection from Bulk 5	Aroma QTL and QTL 2, 7, 9, 11
P170	2003	line selection from Bulk 5	Aroma QTL and QTL 2, 7, 9, 12
K152	2003	line selection from Bulk 5	Aroma QTL and QTL 2, 7, 9, 13

K153	2003	line selection from Bulk 5	Aroma QTL and QTL 2, 7, 9, 14
K166	2003	line selection from Bulk 5	Aroma QTL and QTL 2, 7, 9, 15
Pyramid lines (targeting multiple QTL) 'PY' lines and 'K' lines			
PY81	2002	$BC3F_4$ 23-01-06-06	none (control)
PY82	2002	$BC3F_4$ 21-01-03-11-17	All QTL
PY83	2002	$BC3F_4$ 21-01-03-11-07	All QTL
PY84	2002	$PY2F_2$ #3	All QTL
K174	2003	$PY2F_2$ #3	All QTL
K176	2003	$PY2F_2$ #8	All QTL
K186	2003	$BC3F_4$ 21-01-03-11-09	All QTL
K series†	2003	$PY2F_2$ #3	All QTL

†K189 , K190 , K191 , K196, K205, K206, K208, K216

5. What is the type of output(s) being described here?
Please tick one or more of the following options.

Product	***Technology***	***Service***	***Process or Methodology***	***Policy***	***Other Please specify***
x	*x*		*x*		

6. What is the main commodity (ies) upon which the output(s) focussed? Could this output be applied to other commodities, if so, please comment

The main commodity is rice varieties for cultivation in the rainfed uplands of eastern India particularly by direct seeding (i.e. not transplanted at seedling stage). Some of the output varieties can also be cultivated in the medium-uplands in India.

7. What production system(s) does/could the output(s) focus upon?
Please tick one or more of the following options. Leave blank if not applicable

Semi-Arid	***High potential***	***Hillsides***	***Forest-Agriculture***	***Peri-urban***	***Land water***	***Tropical moist forest***	***Cross-cutting***
x							

8. What farming system(s) does the output(s) focus upon?
Please tick one or more of the following options (see Annex B for definitions).
Leave blank if not applicable

Smallholder rainfed humid	*Irrigated*	*Wetland rice based*	*Smallholder rainfed highland*	*Smallholder rainfed dry/cold*	*Dualistic*	*Coastal artisanal fishing*
x						

*9. How could value be added to the output or additional constraints faced by poor people addressed by clustering this output with research outputs from other sources (RNRRS and non RNRRS)? (**max. 300 words**). Please specify what other outputs your output(s) could be clustered. At this point you should make reference to the circulated list of RNRRS outputs for which proformas are currently being prepared.*

Clustering with RNRRS outputs: The popularisation of these new rice varieties is synergistic with dissemination of the outputs from the rainfed *rabi* (dry season) fallow projects of the PSRP (R809, R8221, R8269) because short duration varieties of rice are compatible with the cultivation of pulses in the rainfed *rabi* fallows. All the new varieties can be further tested in combination with other interventions developed for rice systems in the Crop Protection Programme for improved crop agronomy. Since farmers evaluated the varieties for improved straw for fodder, there is scope for clustering these outputs with those from improved livestock nutrition projects. They may also be clustered with other outputs from COB programmes of the PSRP targeted at other countries (e.g. Nepal, West Africa, Bangladesh).

Validation

B. Validation of the research output(s)

***10. How** were the output(s) validated and **who** validated them?*
*Please provide brief description of method(s) used and consider application, replication, adaptation and/or adoption in the context of any partner organisation and user groups involved. In addressing the "who" component detail which group(s) did the validation e.g. end users, intermediary organisation, government department, aid organisation, private company etc... This section should also be used to detail, if applicable, to which social group, gender, income category the validation was applied and any increases in productivity observed during validation **(max. 500 words)**.*

The process of using MABC in combination with COB in rice for semi-arid production systems was validated in India by CAZS-NR researchers in collaboration with scientists and breeders from the partner organisations BAU and GVT (East) in Ranchi, GVT (West), JNKVV (Indore) and UAS (Bangalore). The results clearly show that high-tech and low-tech approaches can be used successfully in tandem to improve rice breeding programmes – but what are the advantages of this? The best varieties were tested in the All India Coordinated Rice Improvement Project (AICRIP) of the Indian Council of Agricultural Research (ICAR) throughout India.

Figure 1. Farmers selecting in segregating bulks derived from MABC.

The validation of the MABC rice varieties involved field testing by the end users - the resource-poor farmers of both genders in Jharkhand, Orissa and West Bengal (Table 2). They were all smallholder farmers in **rainfed semi-arid** farming systems with no irrigation. Farmers were directly involved in collaborative breeding to select within the segregating bulks containing root QTL (Figure 1).

Participating farmers grew the bulks and lines in ‘mother and baby’ trials (Witcombe, 2002) where mother trials had a full set of test varieties and baby trials comprised of only one test variety compared with a local variety. These trials were conducted under farmers’ own management and were jointly evaluated for quantitative and qualitative traits using household-level questionnaires and focus group discussions led by NGO partners. Evaluation was carried out by participating and non-participating farmers (including women) for pre-harvest traits (e.g. fodder yield, shattering and earliness) and post-harvest traits (e.g. cooking quality, taste, fodder quality and storage properties).

Table 2. Testing of the MABC varieties in on-farm and research station trials co-ordinated by GVT (East) from 2002 to 2006 in Jharkhand, Orissa and W. Bengal.

Product	**When**	**Where**	**Who validated**	**Number of station trials**	**No. of farmers**
Richa 1 to 6	2002 to 2006	Jhar, Oris, W. Bengal, MP, Raj	BAU, GVT, JNKVV, MPUAT	12	444
Pyramid and aromatic (PY 81 to 84, P157, P170)	2003-2006	Jhar, Oris, W. Bengal, MP, Raj	BAU, GVT, JNKVV, MPUAT	12	264
33 pyramid lines with K suffix	2003-2006	Jharkhand	BAU, GVT	7	-

Simultaneously research trials were conducted under conditions similar to farmers’ fields, but with randomised block designs and replication. The MAS bulks and lines were tested under two contrasting water supply treatments: rainfed only and irrigated.

Increases in productivity were observed during the validation, particularly for grain and straw/fodder yield (Steele et al., accepted; Table 3). The MABC varieties excelled in drought resistance compared to both check varieties

(Birsa Gora 102 (BC 102) and Kalinga III).

Table 3. Increases of the best MABC varieties (%) over the most farmer-preferred variety (Kalinga III) for grain yield (GY) and straw yield (SY) in research trials (RT) conducted in eastern India by GVT and BAU and in western India by JNKVV and MPUAT, and in on-farm trials (OFT) in Jharkhand, Orissa and W. Bengal in eastern India, co-ordinated by GVT (East), 2002 to 2005

		Number		Best product increase (%) over Kalinga III			
				GY	GY	SY	SY
Output	**When**	**RT**	**OFT**	**RT**	**OFT**	**RT**	**OFT**
Richa 1 to 6	2002 -04	11	24	18%	24%	10%	15%
PY 82, 83, 84	2002 -04	7	12	20%	24%	25%	Not available
Aromatic lines (P157, P170)	2004-05	1	14	85%†	20%†	22%†	10%†
K series lines	2005	1	0	152%††	-	125%††	-

† Over BG 102 local check.
†† High values because best of several lines evaluated in a single year.

The MABC lines have thicker stems that reduce lodging compared to Kalinga III. The QTLs impart longer and thicker roots (Steele et al., 2006) that can aid performance in drought conditions. PY 83 and PY 84 have 10% and 11% longer roots than Kalinga III. Surprised this is significant given the innate high variability of roots and roo data? The near-isogenic line with only QTL 9 had 23% longer roots than Kalinga III. The varieties showed improvements in other key agronomic traits that make them particularly adapted for the rainfed uplands of eastern India (Table 4).

Table 4. Some of the additional important traits of the new varieties in comparison to Kalinga III and BG 102 check varieties

Variety	Traits (other than yield) in which new varieties excel
Richa 1 to 6	Early maturity, drought tolerance, adapted to low as well as high fertility, lodging resistance, tall-plant type, long-slender grains with good cooking quality, disease resistance, and higher fodder yield with good quality. They are also adaptive to medium lands.
Pyramid (PY) and aromatic (P) varieties	Most traits as above. Aromatic selections from Richa 5 have high quality long and slender grains fetches higher price in the market. They also have higher fodder yield with strong straw for lodging resistance. They are also adaptive to medium lands.
K-lines with all QTL	All varieties have early maturity and high level of drought resistance because of QTL. The grains are long and slender grains with good cooking quality. Plants are taller than the checks that give higher fodder yield. They are also adaptive to medium lands.

*11. **Where and when** have the output(s) been validated? Please indicate the places(s) and country(ies), any particular social group targeted and also indicate in which production system and farming system, using the options provided in questions 7 and 8 respectively, above **(max 300 words)**.*

Research Trials

Validation of MABC varieties in India involved 31 research trials from 2002 to 2006. This was done in Jharkhand by BAU and GVT (East); in Madhya Pradesh by JNKVV and in Rajasthan by MPUAT in collaboration with GVT (West). [See also Tables 2 and 3].

Validation of three bulks and one line has also been carried out in Initial variety trial (early maturity) (IVT E) tests across India in the All India Coordinated Rice Improvement Project (AICRIP) trials of the ICAR from 2002 to 2006 (Table 5).

Table 5. MABC varieties tested in All India Coordinated Rice Improvement Project (AICRIP) Trials of the Indian Council of Agricultural Research (ICAR) from 2002 to 2006

Variety	When
Richa 2	2002
Richa 5	2004
Richa 6	2006
PY 84	2006

On-farm Trials

Resource-poor farmers in eastern India first grew segregating bulks of MABC in 2000 for COB. All testing was carried out under rainfed conditions. Selected bulks were validated between 2002 and 2006 in on-farm trials by 708 farmers across the three states of Jharkhand, West Bengal and Orissa. These trials were co-ordinated by GVT (east) in villages in the rainfed uplands and medium-uplands. [See also Tables 2 and 3]. The farmers who participated were all members of 'self-help' groups established by GVT (East). Eleven 'mother trials' were used to validate the PY lines (Table 6; Steele et al., accepted).

Current Situation

C. Current situation

12. ***How and by whom*** *are the outputs currently being used? Please give a brief description* ***(max. 250 words****).*

The MABC varieties are currently being used by **researchers** at BAU (Ranchi) and **smallholder farmers** who participated in GVT (East) testing and dissemination programmes.

During testing from 2003 to 2006 seeds of Richa, PY and Aromatic varieties developed by MABC were distributed to 708 farmers for mother and baby trials (Table 7). These farmers were encouraged to save the seed of the varieties that they would like to continue to cultivate. Therefore, seed is only currently being used if it has been saved from the on-farm trials. Informal surveys have shown that some farmers have continued to grow them on a limited scale. There has also been some farmer-to-farmer seed exchange, but at a slow rate. Farmer-to-farmer spread is subject to deterioration of quality due to admixtures during multiplications and exchanges.

There has been no large scale scaling up of the MABC varieties by producing and disseminating their seed. There is no official mechanism to produce seed of un-released varieties. All of the seed currently available has been produced informally. Initiatives could readily be made by GVT (East) to produce truthful seed for dissemination, but this requires financial support.

Table 7. Number of farmers given seed and area of land cultivated with MABC varieties from 2002 to 2006

Year	No. of farmers given seed of Richa 1 to 6	Area under Richa 1 to 6 (ha)	No. of farmers given seed of PY and Aromatic varieties	Area under PY and Aromatic varieties (ha)
2002	72	18.0	0	0
2003	87	10.4	6	0.6
2004	195	24.0	186	23.1
2005	45	5.3	36	4.4
2006	45	5.3	36	4.4
Cumulative Total	**444**	**63.0**	**264**	**32.5**

*13. **Where** are the outputs currently being used? As with Question 11 please indicate place(s) and countries where the outputs are being used **(max. 250 words).***

The lines and bulks are being used in eastern India by resource-poor smallholder farmers of rainfed uplands and medium uplands across the three states of Jharkhand, Orissa, West Bengal.

Researchers and breeders at BAU and GVT (East) in Ranchi (Jharkhand) are using the varieties in research trials and proposal for release in the formal system. Some of the varieties are undergoing testing in the All India Rice Improvement Project (AICRIP) of the ICAR throughout India.

GVT (East) directly operates in 13 districts of Jharkhand (Ranchi, Palamu, Hazaribagh, West Singhbhum, Kharsavan, Goda, Gumla, and Bukaro), Orissa (Dhenkanal, Keonjhar, Mayurbhanj) and West Bengal (Midnapur and Purulia) for improvement of livelihood of 0.4 m people majority of whom have:

- 86 to 93 % are smallholders (< 2 ha) with fragmented land holding 'without majority' ??? of rainfed crops areas (5% of land irrigated in Orissa, 8% in Jharkhand and 13% in W. Bengal)
- Rice is the major crop in three states with about 31% medium and 23% lowland which is mostly rainfed and the crop is prone to frequent droughts.
- 65% households live below the poverty line (BPL).
- Livelihoods are based mainly on agriculture and migration.
- Low literacy rates (<40%)

*14. What is the scale of current use? Indicating how quickly use was established and whether usage is still spreading **(max 250 words).***

At present the scale of use of the MABC varieties is limited. There has been no organised seed production, hence use of these varieties is limited to the farmers who took part in trials, and some of their close neighbours. Only seed saved by the 708 farmers who participated in mother and baby trials has been available for use by farmers. We estimate that the total area covered by these varieties in 2006 was approximately 100 ha across three states (Jharkhand, Orissa and West Bengal).

Many of the participating farmers preferred the MABC varieties over local varieties for rainfed uplands. Informal surveys show they have continued to grow them where possible.

Large-scale dissemination of these varieties is required in order for them to cover a significant proportion of the upland rice area. The total rainfed upland area in eastern India is about 5 M ha (Muralidharan et al., 1988). Of this, about 2 M ha is located in Jharkhand (0.4 M ha), Orissa (0.7 M ha) and West Bengal (0.9 M ha). If they were to replace existing cultivars across 10% of the upland area of three eastern states there would be a demand of 20,000 t of seed. The land area on which these varieties could be grown is likely to be much greater. In years when the monsoon rains are late, farmers chose to plant early-maturing upland varieties in medium-upland areas, instead of later maturing varieties that would normally be grown. The MABC varieties are likely to be a popular choice to replace local upland varieties for this purpose because they respond better to more favourable conditions.

The use of MAS techniques in combination with COB is not currently being practiced by any national or international programme. Successful release and dissemination of varieties developed by the novel approach would highlight the potential, and encourage other rice breeders to combine these methods to increase their success rate.

15. In your experience what programmes, platforms, policy, institutional structures exist that have assisted with the promotion and/or adoption of the output(s) proposed here and in terms of capacity strengthening what do you see as the key facts of success? ***(max 350 words).***

The varieties derived from MABC have not yet been formally released although some of them have been tested in the formal trials at state and national levels. We believe that many of them should be released.

The promotion of varieties in these poor areas of India has been inefficient as the areas are remote, the purchasing capacity of the farmers is low, and the demand for seed unpredictable because it varies with the rains. Farmers also have limited access to the government extension services. The extension strategy assumes that farmers will visit the local farm science centre (KVK) but few farmers have the resources to do so. Front line demonstrations by State Departments of Agriculture are few and conducted in more favourable agricultural environments. Hence, the main activities for dissemination of seed have been through projects such as:

Eastern India: Village level farmers' cooperatives and groups, self help groups of GVT and NGOs, village Panchayats, National Agricultural Banking for Rural Development (NABARD), National Agricultural Marketing Federation (NAFAD), Council for Advancement of People's Action and Rural Technology (CAPART), Catholic Relief Services (CRS), Poorest Area Civil Society Programme (PACS) of Govt India that is supported by DFID.

Clearly, there is a need for building capacity to raise awareness of these new varieties and technology using existing networks.

Key factors of success are:

- Capacity building of GOs, NGOs and farmer groups in all aspects related to PVS, seed production and the new varieties.
- Large-scale seed production and distribution of new varieties. Encouraging community-based seed production (see PSP dossier 36).
- Creating awareness with the stakeholders for the new varieties through meetings, demonstrations and publication of literature.

Policy: In India proposals for the release and notification of new varieties are submitted by breeders through their respective institute of ICAR or State Government. Proposals are considered by a sub-committee and a successful variety is released by a State Seed Committee or by the Central Seed Committee (for more than one state). Seed is certified by the State Seed Certification Agency established under the State Governments. Once a variety is officially released there is no restriction on certified seed production and dissemination.

Government agencies (state department of agriculture and agricultural universities) do not encourage the spread of non-released varieties. However, private companies and NGOs can carry out truthful seed production of non-released varieties, provided they have sufficient resources. Seed spread via the informal sector is slow, whereas official release would involve promotion by the official seed agencies in different states across India.

Current Promotion

D. Current promotion/uptake pathways

*16. **Where** is promotion currently taking place? Please indicate for each country specified detail what promotion is taking place, by whom and indicate the scale of current promotion **(max 200 words).***

In India, the unreleased MABC varieties for rainfed uplands are being promoted in Jharkhand, Orissa and West Bengal by the GVT (East). As described in section 14 (above) the scale of adoption is limited because there has been no seed production. No dissemination has taken place through the GOs because the varieties are not yet released. Once one or more of them are released, BAU could produce seed to supply Jharkhand and the other eastern states.

Scope exists for the promotion of the MABC new varieties for use by farmers in other Indian states where rice is grown in the rainfed uplands. These include eastern Uttar Pradesh, Chhattisgarh, Rajasthan, Gujarat, Madhya Pradesh and Tamil Nadu. The adoption of unreleased varieties can only be through the informal sector by truthful seed production. Therefore, formal release of these varieties is the preferred mechanism for the uptake, however this will require discussions between GVT and BAU and the compilation of existing data.

The use of the combined technologies of MAS and COB for rice improvement has been publicised internationally by CAZS-NR, BAU and GVT scientists. This has been at international and national crop breeding conferences.

17. What are the current barriers preventing or slowing the adoption of the output(s)? Cover here institutional issues, those relating to policy, marketing, infrastructure, social exclusion etc. ***(max 200 words)****.*

The combination of COB and MAS techniques is only likely to be adopted by national plant breeding programmes if successful varieties are released that have been developed using these methods. Therefore, the lack of release and uptake of these varieties is a barrier to the spread of the technology.

Barriers to release and uptake of MABC varieties
The release process in India is cumbersome with a long delay between testing and release and between release and dissemination in the GOs sector. State agricultural universities and state departments of agriculture are responsible for seed production of released varieties.

Some of the MABC varieties have already been tested over three years in research and on-farm trials. However, current release protocols require that they undergo further testing. Policy makers in India are not aware that delaying the release of a farmer-preferred variety results in a huge loss of potential yield to the farmers.

Seed of non-released varieties can be multiplied and sold at Truthfully Labelled (TL) seeds. NGOs and private companies can be to do this if there are financial incentives. So far, they have been reluctant to carry out seed production of upland varieties because the profit margins are low for seed targeted towards marginal farmers who cannot afford to pay high prices.

Policy issues: The release process is controlled by government organisations and NGOs cannot propose varieties for release directly. The formal trials system often recommends varieties that have only been tested in research station environments that may be very different to those of farmers' fields. The formal system of adaptive trials excludes poor farmers and women farmers because officials prefer to conduct trials with better-off farmers. All these issues are a barrier to the release of varieties that are highly suitable for farmers but may not perform exceptionally well in on-station trials.

18. What changes are needed to remove/reduce these barriers to adoption? This section could be used to identify perceived capacity related issues ***(max 200 words).***

The most important factor to remove the barriers is to raise awareness of the characteristics and value of the new varieties at all levels (State Agricultural Universities, NGOs, Departments of Agriculture, the private sector, and farmers) and over the wide geographical area to which they are adapted. This will help in the dialogue to achieve the formal release of the best varieties and will create demand for the seed. Moreover, not only is there a lack of awareness of the new rice varieties but also no public analysis has been done of the constraints to delivering seed of upland rice varieties in adequate quantities.

Changes in seed production to remove barriers to adoption require learning on how to most effectively put research into use. The following is a brief analysis of possible changes.

A major change would be the production of seed by private sector companies, a model we are currently attempting to test in eastern India in Chhattisgarh for seed supply to private sector seed merchants in Jharkhand. However, the economics of off-season upland rice in irrigated conditions (the seed production environment that has to be used in the current model of minimising the delay between production and sales) is not clear. There is also the issue as to whether the capacity exists in the private sector of producing large quantities of upland rice seed when so little has been supplied in the past.

Community-based seed production (see PSP dossier 36) may be an option but it requires that the barriers to direct private sector collaboration with the groups is overcome. Self-help groups of NGOs can quite easily be trained in seed production techniques, as has already been done by GVT over several years, but for viable seed enterprises it is more important to give training in business and marketing, something that NGOs and GOs are poorly equipped to do. Self-help groups can try an alternative model of producing seed in the main season (instead of irrigated conditions in the dry season). This has advantages:

- seed is produced under conditions (season and upland environment) to which the variety is adapted
- seed can be locally produced as the geographical area of production is not restricted by the availability of off-season irrigation water; and
- the potential area of production is much larger than for the irrigated off season.

The disadvantages are that the harvest could be affected by rain (but then the seed can be sold as grain) and, perhaps critically, that seed has to be stored over the rainy season. The latter requires access to credit and access to physical infrastructure.

Removing the barriers that prevent the uptake of MAS combined with COB rice breeding programmes in India and other countries.

- The release of MABC varieties will encourage the adoption of MAS tools and techniques in national rice breeding programmes.
- Investment in COB programmes to develop the results of second cycle crosses between successful MAS and COB varieties.

19. What lessons have you learnt about the best ways to get the outputs used by the largest number of poor people? ***(max 300 words).***

- ‘High-tech’ marker assisted selection approaches can be successfully combined with ‘low-tech’ client oriented breeding to develop rice varieties that have the desired range of traits desired by resource-poor farmers. Thus, poor people can be directly involved in the development of products from ‘high-tech’ programmes, and this makes the products more suited to meet their needs. For example, if we had MAS alone the ‘ideal’ genotypes with the ’best’ set of root QTLs would have been too late in maturity to be of use to upland farmers. By involving farmers, we did not waste resources in developing such lines, but were able to concentrate on combining the most appropriate QTLs with the most appropriate farmer-preferred traits. Rice breeders must be made aware of this finding.

- The success of a variety in only a few hundred participatory trials does not lead to its dissemination and uptake by more farmers. There must be co-ordinated, large-scale intervention for seed production and dissemination. The involvement of NGOs can strengthen community-based seed production to make seed supply locally sustainable.

- The formal variety release programme is not suited to the release of varieties developed in participatory approaches through NGOs, however the products of such COB are often more suited for use by farmers in marginal environments than those currently being developed in national breeding programmes.

- Wider dissemination, in the form of publications and manuals, is required for MAS tools and protocols, designs and management strategies for on-farm experiments and community based seed production.

Impacts On Poverty

E. Impacts on poverty to date

20. Where have impact studies on poverty in relation to this output or cluster of outputs taken place? This should include any formal poverty impact studies (and it is appreciated that these will not be commonplace) and any less formal studies including any poverty mapping-type or monitoring work which allow for some analysis on impact on poverty to be made. Details of any cost-benefit analyses may also be detailed at this point. Please list studies here.

The MAS varieties are the product of a long-term investment from the DFID PSP that had many stages. These stages were the identification of QTLs for improved roots, the development of selectable markers, the identification through PVS of a suitable variety for improvement, numerous generations of backcross breeding, client-oriented breeding and validation of lines and bulks with farmers and researchers. The final products were not made widely available to farmers who could benefit from them because the PSP funding ended. Therefore, we cannot assess the direct impact of adoption of MABC products.

We list below surveys that were carried out to assess the impact of two other rainfed upland varieties developed through COB (without MAS) in eastern India, Ashoka 200F and Ashoka 228. The expected demand and impacts of the MABC varieties are likely to be similar.

1. Virk, D.S., Bourai, V.A., Choudhary, A., Misra, M. & Witcombe, J.R. (2003). Participatory crop improvement in eastern India: An impact assessment. PSP Annual Report 2003 Section 1: Introduction and General Overview. Research Outcomes. pp 26-33.
2. Virk, D.S., Bourai, V.A., Choudhary, A., Misra, M., Mottram, A. & Witcombe, J.R. (2005). Highly client oriented breeding: The impact of two upland rice varieties in eastern India. CAZS Discussion Paper 7, pp. 1-11.
3. Mottram, A. (2005). Impact of new upland rice varieties in eastern India from client-oriented breeding: evidence from whole village surveys. Available at www.dfid-psp.org, pp. 1-15.
4. Virk, D.S., Bourai, V.A., Choudhary, A., Misra, M.& Witcombe, J.R. (2004). Participatory crop improvement in eastern India: An impact assessment. Plant Sciences Research Programme: Highlights & Impact. Participatory crop improvement. Pp. 87-96.

A cost-benefit analysis of the adoption of Ashoka 200F and Ashoka 228, in three states of eastern India

(Jharkhand, Orissa and West Bengal), has been carried out with the following assumptions:

- A two-fold rate of spread of these varieties in all three states.
- An adoption ceiling of 40% of the upland rice area.
- An increased benefit per hectare of £33 per hectare (500 kg additional yield at £0.09 kg^{-1}) for both varieties.
- A research expenditure of £0.5 million by 2002, and a further annual expenditure of £100,000 for research and development.

The anticipated cumulative benefits by 2010 are expected to be more than £100 m. This is much greater than the total expenditure of £20 m on the Plant Sciences Research Programme 1995-2005 (Figure 2).

Figure 2. Net Present Value (NPV) and Internal Rate of Return (IRR) over time from the new rice varieties using the assumptions described in the box above.

The MABC varieties are not only suited to the same upland areas as the Ashoka varieties used in this model but are predicted to generate a greater economic impact because they are responsive to inputs and so are likely to be grown by farmers in the more favourable medium uplands in years of low or late monsoon rainfall. Focus group discussions and household level questionnaires have shown that farmers think that the MABC varieties are suitable for upland and medium land cultivation. They are likely to fetch higher market prices than existing upland varieties because of their slender grains and in some lines, aroma. Thus, the availability of these varieties will increase the options and opportunities available to resource-poor farmers. But more farmers need to be made aware of their existence before these benefits can be detected.

21. Based on the evidence in the studies listed above, for each country detail how the poor have benefited from the application and/or adoption of the output(s) ***(max. 500 words):***

- *What positive impacts on livelihoods have been recorded and over what time period have these impacts been observed? These impacts should be recorded against the capital assets (human, social, natural, physical and, financial) of the livelihoods framework;*
- *For whom i.e. which type of person (gender, poverty group (see glossary for definitions) has there been a positive impact;*
- *Indicate the number of people who have realised a positive impact on their livelihood;*
- *Using whatever appropriate indicator was used detail what was the average percentage increase recorded*

Impact studies have yet to be carried out for the MABC varieties. We can extrapolate from the impact studies and livelihoods analyses conducted for Ashoka 200F and Ashoka 228 (rainfed upland varieties) in eastern India since 2002, on 15% of the households who have received seed of the Ashoka varieties.

Benefits of the varieties: The Ashoka varieties have favourable characteristics that are required by the subsistence farmers (of all poverty groupings and both genders) for rainfed upland ecosystems (Virk et al., 2003, 2004, 2005; see 20 above) in Jharkhand, Orissa and West Bengal. Ashoka varieties were cultivated on 63% of the land in some survey villages. Most farmers who continue to grow the Ashoka varieties gave the following reasons:

- Earlier maturity than currently available improved varieties.
- Drought tolerance.
- Long and slender grains with good cooking quality.
- Higher grain and fodder yield.
- Weed competitiveness.
- Higher market price than the coarse-grained local varieties.

The MABC varieties incorporate all of the above traits. In addition they have high lodging resistance due to stronger straw and better rooting due to root QTLs. Some of them (Richa 5, P157 and P170) have the value-added trait of aromatic grains.

Effect on livelihoods: The survey by Mottram (2005) farmers showed that the benefits of cultivating Ashoka varieties have had a major impact on their livelihoods. **Farmers said that food is now available in years of poor rainfall and during the lean periods of the year, and straw is available for fodder earlier in the season.** Additional cash from the sale of surplus grain, or because grain no longer has to be purchased for household needs, can be used for various purposes such as children’s education, food and clothes. However, the most important impact, reported by a majority of farmers, was that **cultivation of the Ashoka varieties results in increased household food security** – on average by 1-2 months, in some cases, enabling grain-deficit households to become self-sufficient.

Farmers take into accounts the trade-offs between a complex array of traits (e.g yield versus maturity; grain quality versus drought tolerance) when they decide to adopt a new variety. The new MABC varieties offer them a wide choice of good traits which can lead to the adoption of more than one variety by farmers and increase in varietal diversity in participating villages. The average percentage increase in yield for these varieties is 25% improved grain yield and 15% improved straw yield over Kalinga III.

Environmental Impact

H. Environmental impact

24. What are the direct and indirect environmental benefits related to the output(s) and their outcome(s)? ***(max 300 words)***

This could include direct benefits from the application of the technology or policy action with local governments or multinational agencies to create environmentally sound policies or programmes. Any supporting and appropriate evidence can be provided in the form of an annex.

Adoption of the MABC varieties will lead to a direct increase in productivity per unit area without the use of additional external inputs (fertiliser, pesticides, irrigation). This can be achieved without changes in management practices and is
environmentally beneficial. The land area required to increase productivity under these varieties will not increase, so as a direct result of adoption there will be less demand to clear new areas (e.g. forests) for cultivation.

The higher straw yields should reduce the pressure of deforestation for wood and animal fodder.

Adoption of earlier maturing varieties will allow farmers to cultivate rainfed *rabi* crops such as chickpea that can indirectly improve soil fertility.

By promoting a range of new varieties, farmers will gain access to a wide choice of genotypes and this can lead to increased diversity on a farm or regional level. A more diverse range of varieties cultivated in one season reduces crop loss due to pests and diseases and indirectly reduces the use of pesticides.

COB has ensured that the new varieties are resistant to the common diseases and pests found in the target environment. Therefore they are less likely to lead to an increase in the use of water-polluting agro-chemicals soil pollutants than modern varieties developed for non-target environments. Fewer pesticides and insecticides will reduce the risks to human health and will give a better balance to the natural pest-predator cycle.

25. Are there any adverse environmental impacts related to the output(s) and their outcome(s)? ***(max 100 words)***

The MABC varieties produce higher yields with the same levels amount of inputs compared to currently available upland rice varieties. However, they also respond very well to increased fertiliser and, if this is profitable farmers may be tempted to increase the levels of such inputs, that could lead to environmental problems associated with high fertiliser use. The cultivation of aromatic varieties on a large scale may attract more insects, so could lead to increased insecticide use. The increased economic benefits to the communities will lead to higher living standards including greater consumption of consumer goods, more vehicles a corresponding increase in environmental pollution. All of these possible adverse environmental impacts must be considered in the context that the current options are limited for these people, and poverty reduction is the overall goal.

26. Do the outputs increase the capacity of poor people to cope with the effects of climate change, reduce the risks of natural disasters and increase their resilience? ***(max 200 words)***

High investment in research and development has led to the development of rice varieties that produce greater biomass with less water than existing varieties because they have more effective root systems. These MABC varieties are ideally suited for cultivation by upland farmers where water is limited as has been repeatedly observed during participatory evaluations. Climate change is predicted to increase the area of land that is rainfed and prone to drought, so the development of these varieties is timely and the need for them is likely to increase. Poor people in eastern India are amongst those who are likely to be affected first and most severely by climate change.

The successful adoption of two other upland varieties by smallholder farmers in eastern India has led to increased economic benefits from enhanced grain and fodder yields. Varietal diversification is a means that farmers can use to cope with increasingly frequent but unpredictable droughts. Deployment of varieties with different dates of maturities can spread out water demands and allow *rabi* crops to be grown. Increased crop diversity can reduce the risks from natural disasters such as diseases and pests. Deployment of varieties that yield well under low fertiliser and low or no irrigation but respond well to better conditions, can help to manage risk. This increases the resilience of farmers to cope with natural risks.

Annex

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