Participatory Plant Breeding in Rice for High Potential Production Systems in the Terai and Low Hills of Nepal

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Acronyms

ADO	Agriculture Development Office
BLB	Bacterial Leaf Blight
BPH	Brown Plant Hopper
CBO	Community Based Organization
DADO	District Agriculture Development Office
DFID	Department for International Development
DOA	Department of Agriculture
ESD	Equal Seed Descent
G x E	Genotype-by-Environment Interaction
HPPS	High Potential Production System
INGO	International Non-government Organization
IPB	Irradiated Pusa Basmati-1
LI-BIRD	Local Initiative for Biodiversity, Research and Development
LoA	Letter of Agreement
LSW	Long-standing Water
NARC	National Agriculture Research Council
NGO	Non-government Organization
NRRP	National Rice Research Programme
PCI	Participatory Crop Improvement
PPB	Participatory Plant Breeding
PVS	Participatory Varietal Selection
VDC	Village Development Committee
WBPH	White Backed Plant Hopper

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Executive Summary

We started participatory plant breeding (PPB) in rice for high potential production systems (HPPSs) in the inner *terai* (Chitwan and Nawalparasi districts) and low hills of Nepal in March 1998. The project purpose was to test the applicability of PPB to more favourable environments. To do this we developed productive strains and genotypes through PPB and promoted them in the target environments.

The programme was initiated with F_3 lines of two crosses obtained from GVT East, India. A few carefully chosen crosses were subsequently made, involving a large population size targeted for different rice production systems in *Chaite* and Main seasons. The project activities included selection of genotypes in the target environments; involvement of participating farmers in pre- and post-harvest evaluation; testing advanced lines widely; scaling-up PPB processes and products, and dissemination. By the end of the 2001 Main season, we had selected 72 advanced breeding lines from seven crosses.

Simple modified bulk and equal seed descent (ESD) breeding methods were used to extract these lines, which allowed increased farmer participation in the programme. Farmers selected during pre- and post-harvest evaluations of genotypes. Organoleptic taste assessment and micromilling were important selection criteria. The seed of superior lines were increased and tested in a wider area through another DFID/PSP project, R8071.

In an effort to integrate the products of PPB into the national system, *Chaite* and *Barkhe* lines were included into national disease-screening nurseries of the National Rice Research Program. It was found that PPB products are resistant to, or tolerant of, blast (leaf and neck blast) and bacterial leaf blight (BLB). PPB in HPPSs has been successful in generating breeding lines of diverse duration suitable for varying production environments and input levels, and having tolerance to a range of abiotic and biotic stresses. Furthermore, partnerships with CBOs, NARC and DOA were established to share new knowledge, as well as disseminate PPB outputs to the stakeholders. The outputs of this project have thus directly contributed to DFID's development goals.

1 Background

- In the *Chaite* season (early rice), CH-45 is the most preferred and widely grown variety. It is about 40 years old, and is prone to diseases such as rice blast caused by *Pyricularia grisea,* and to damage by the white-backed plant hopper (**WBPH**). Similarly, in the Main season, Masuli is the most dominant variety in Chitwan and Nawalparasi districts, although it is highly susceptible to leaf and neck blast, and to damage by the brown plant hopper (**BPH**). In the lowlands, Masuli is also prone to lodging.

- A few, widely adapted rice varieties are promoted by the formal system throughout the country, but without due consideration to the diversity in environmental and socio-economic conditions.

- Farmers' participation in the selection of suitable plant types is uncommon in conventional breeding systems. There is also a lack of participation by farmers in the assessment of post-harvest qualities and market acceptability of rice varieties.

- In conventional breeding systems, testing of advanced breeding materials is conducted within the confines of the research station. Farmers are involved as part of the variety release requirements, rather than to assist in variety development or to help make final decisions on acceptance or rejection of breeding lines.

- Generally, NRRP develops and recommends varieties mainly for use in the larger (districts/regions), such as Eastern Terai, Central Terai, Western Terai, Mid Hills and High Hills, although there are considerable differences within all these environments. Variety release by the formal sector is very slow process, and farmers get the finished products very late in the process.

- The baseline survey of PCI project in HPPSs in Chitwan indicated that there is lack of varietal choice in HPPSs (Rana *et al.,* 1999).

- Sthapit *et al*. (1996) demonstrated for a marginal agricultural environment for rice (high altitude) that farmers' involvement in selection in the early stages successfully produced farmers' preferred crop varieties. Hence, it was possible that PPB could also be effective in HPPSs.

- PPB allows involvement of farmers in the initial stages of generation segregation so that they can select preferred breeding lines (Sthapit *et al.,* 1996). Farmers' preferences and needs, market acceptability, variety testing and verification are all addressed simultaneously, so that the cost of variety development is reduced. PPB thus minimises the risk of varieties being rejected by farmers late in the breeding process, which is a common problem in the conventional system.

2 Project Objectives

The objectives of the project were:

- To develop methods for PPB for HPPSs
- To develop productive strains/genotypes through PPB;
- To promote PPB products in target environments.

3 Mandate Crops

- *Chaite* season rice (*Judi* or early rice)
- Main season rice (*Barkhe* rice)

4 Research Activities

4.1 The hybridisation programme

By the end of 2000, seven hybridised populations of rice had been developed from carefully selected parents for each of the target environments (Table 1). The Kalinga III/IR 64 cross was a wide cross between an upland and a lowland variety where both varieties had shown wide adaptation. Other crosses involved a locally adapted parent (e.g., Masuli, or CH45, or Jetho Budho, which is an important aromatic landrace from Pokhara valley of Nepal, that was crossed to Pusa Basmati-1 in order to improve the lodging resistance and post-harvest qualities of Jetho Budho. Other crosses involved varieties that was liked in PVS (e.g., Radha 32 or Pusa Basmati-1) but had an identified weakness.

Table 1. The hybridisation program and target rice growing environments of PPB in HPPSs in Chitwan, Nepal.

Name of the crosses	Year of crossing	Target Rice-growing Environments
KIII/IR64	F_3 seed in 1998	Upland to lowland, *Chaite* and *Barkhe* season
Masuli/IR64	2000 Main season	Medium upland to lowland *Barkhe* season
Masuli/MT4	1999 Main season	Upland to medium lowland *Barkhe* season
CH45/MT1	1999 Main season	*Chaite* season
Pusa Basmati-1 (Irradiated)	Irradiation in 1998	*Barkhe* season
Pusa Basmati/Jetho Budho	1998 Main season	Medium upland to medium lowland
Radha 32/KIII	1998 Main season	*Chaite* to *Barkhe* season

4.2 Defining rice production system in PPB/HPPS - Chitwan

The definition of rice production systems in PPB/HPPS has helped to identify the right domain of particular breeding lines, and has improved the management of these lines more efficiently in terms of testing in the target environments. This system of defining rice production environments has been adapted to other projects of LI-BIRD, such as PCI and PVS of rice through the Agriculture Research Extension Project (AREP). Rice production environments in HPPSs in Chitwan, both for *Chaite* and *Barkhe* seasons, are defined in Table 2.

Table 2. Breeding lines used in PPB in HPPSs for target production environments, and popular varieties in each production system in Chitwan.

Season	Name of Lines/Series	Production Environments	Popular Varieties
Chaite			
	Judi† 100	Upland	Kalinga III
	Judi 100	Medium Upland	CH 45
	Judi 500	Lowland/Irrigated	BG 1442
***Barkhe*/Main**			
	Barkhe§ 1000	Upland	Radha 4
	Barkhe 1000	Medium Upland	BG 1442, Sugandha-1
	Barkhe 2000	Medium Lowland	Masuli, Sabitri
	Barkhe 3000	Lowland	Masuli, Swarna

† *Judi* indicates breeding lines of *Chaite* season.
§ *Barkhe* refers to Main season rice lines

4.3 Methods of PPB in HPPSs

The PPB of rice was started in March 1998 in the HPPSs of Chitwan district, Nepal. The project included Champanagar, Devnagar, and Amarbasti villages of Geetanagar Village Development Committee (VDC), and Parbatipur village of Parbatipur VDC.

We evaluated several breeding methods including pedigree, modified bulk and equal seed descent (ESD). Modified bulk or ESD methods were equally efficient for extracting superior genotypes. Furthermore, these methods are simple and require less breeder input, and facilitate higher participation of farmers in the breeding programmes. Hence, most of the promising lines were produced by the modified bulk and ESD methods (Annex 1).

4.4 Advanced Breeding Lines of PPB/HPPSs

Seventy-two advanced breeding lines have been developed from the KIII/IR64 cross. Of these, 24 advanced breeding lines have been identified as highly promising or preferred by farmers (Annex 1). This supports the hypothesis that carefully selected parents in a breeding programme can generate progeny with diverse qualities for different production environments. The progeny of this one cross were tested across the production environments to identify lines suited to particular environments.

A number of lines were derived from the irradiated Pusa Basmati-1 population (Annex 1). This included three breeding lines for upland conditions, 13 for a medium lowland environment, and one for lowland conditions. This population produced the highest number of *Barkhe* lines for medium-lowland conditions, but no lines for the *Judi* (*Chaite*) environments, almost certainly because Pusa Basmati-1 is adapted to medium upland to medium lowland main-season environments.

The most farmer-preferred varieties are summarised below:

Judi 102 *Judi* 103 *Judi* 115 *Judi* 503 *Judi* 506 Plot 161	Preferred for earliness, good grain yield and post-harvest performance
Barkhe 1005 *Barkhe* 1027 Sugandha-1	Preferred for upland and medium upland conditions. Sugandha-1 was liked for its aroma and good cooking qualities.
Barkhe 2001 *Barkhe* 2026 *Barkhe* 2027 *Barkhe* 2034 *Barkhe* 2035	Preferred for optimum production environments (some farmers were willing to test *Barkhe* 2001 and *Barkhe* 2027 in long-standing water (LSW) conditions).
Barkhe 3004 *Barkhe* 3009 *Barkhe* 3010	Preferred for (LSW) environments

4.5 Collaborative PPB of Judi Rice

We conducted collaborative PPB trials during the *Chaite* season with four modified bulks. These modified bulks were all selected from a bulk derived from the cross Kalinga III/IR64 and sub-bulks (varieties) were derived on the basis of maturity and plant height. The four modified bulks were:

- *Judi* 102 (Early, tall)
- *Judi* 111 (MT1, earlier, shorter in the medium tall group)
- *Judi* 112 (MT2, earlier, taller in the medium tall group)
- *Judi* 521 (MT3, later, shorter in the medium tall group)

Initially, 24 farmers were distributed 1 kg of seed of each bulk for the *Chaite* season of 2001. Six farmers each got one of these varieties. Before distribution of the bulks, a brief introduction to bulk materials and how to make further selections from these bulks was given to all the farmers. Acceptance and further selection of these bulks was then monitored for each of the cropping seasons. *Judi* 102 was the most promising and most acceptable among the four bulks (Figure 1) because it was the earliest and tallest - both earliness and tall plants are liked by farmers - and good cooking quality made it more acceptable than the previously popular local variety CH 45.

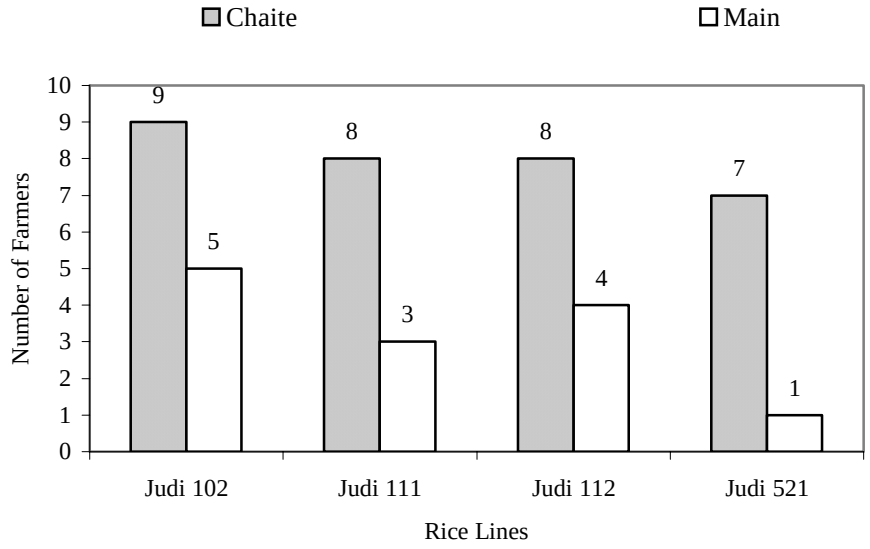

Figure 1. Number of farmers who selected *Judi* lines in the *Chaite* season, and multiplied seed in the Main season.

4.6 Seed Multiplication of PPB lines for dissemination

In 2001, six *Judi* and 18 *Barkhe* lines were multiplied (Annex 2). The purposes of seed multiplication of these lines were:

- To produce enough seeds for testing these lines in a range of production environments covering a wider area;
- Wider testing of PPB products by conducting mother and baby trials through LI-BIRD's network with DADOs in several districts.

There is a lack of varietal choice in optimum and LSW in HPPS in Chitwan, as well as throughout the country. In the multiplication programme we have six promising genotypes for optimum growing conditions and four for LSW environments (Annex 2). Other promising genotypes for these production environments have been multiplied by farmers and seed production groups.

4.7 Generation Advance

Lines for the *Chaite* season are advanced in the main season, but only evaluated in the target production environments in the *Chaite* season. This system has facilitated rapid generation advance, but there was a lack of such a system for the main season. However, in 2001 the *Pushe Dhan* system in Taruwa village in Nawalparasi district was discovered. In this production system, farmers establish a nursery in warm spring water in December, transplant seedlings at the end of January and harvest rice at the end of April. This system of rice production holds a great potential for rapid generation advance for main season breeding materials.

4.8 Disease Screening Nursery in NRRP

To integrate the PPB products into the national testing system, 16 advanced PPB rice breeding lines were included in 2001 in the national disease screening nurseries of the

NRRP in Hardinath for blast (leaf and neck blast) caused by *Pyricularia grisea*, and bacterial leaf blight (BLB) caused by *Xanthomonas oryzae* (Table 3). Lines being tested for blast were screened using a natural pathogen inoculum, while lines for BLB were screened using artificial inoculum consisting of virulent isolate collected from elsewhere. There was sufficient pathogen inoculum for leaf blast this year, but neck blast pathogen pressure was low. The result of these tests showed that almost all lines were resistant to blast pathogen, whereas these lines were moderately resistant or susceptible to BLB. *Judi* lines were mostly susceptible to BLB a disease that is not economically important in the *Chaite* season. Most of the *Barkhe* lines, however, are resistant to BLB because of selection under higher disease pressure in the main season. The PPB lines will be included in disease screening nurseries on a regular basis.

Table 3. Disease reaction of advanced breeding lines of PPB/HPPSs of Chitwan included in National Leaf Blast, National Neck Blast and National Bacterial Leaf Blight Screening Nurseries in National Rice Research Program, Hardinath, main season 2001.

SN	Pedigree	Name	Selection History	Source	Disease Reaction		
1. Advanced Chaite season lines					**Leaf Blast**	**Neck Blast**	**BLB**
1.	KIII/IR-64	*Judi* 101	F3BC98/MTBM98/S119C99/BM99/BC00/BC01	Plot # 119	R	R	S
2.	KIII/IR-64	*Judi* 102	F3BC98/ETBM98/BC99/BM99/BC00/BC01	Early tall	R	R	MS
3.	KIII/IR-64	*Judi* 111	F3BC98/MTBM98/MT1BC99/BM99/BC00/BC01	MT1	R	R	MS
5	KIII/IR-64	*Judi* 521	F3BC98/MTBM98/MT3BC99/BM99/BC00/BC01	MT3	R	R	MR
7	KIII/IR-64	*Judi* 503	F3BC98/ETBM98/S142C99/BM99/BC00/BC01	Plot # 142	R	R	MS
2. Advanced Main season lines							
1.	PB selection	*Barkhe* 2001	M1BM98-S75M99-BM00-BMO1	IPB plot # 75	R	R	MR
2.	PB selection	*Barkhe*2026	M1BM98-S11M99-BM00-BMO1	IPB plot # 11	R	R	MR
3.	PB selection	*Barkhe*2006	M1BM98-S79M99-BM00-BMO1	IPB plot # 79	R	R	MR
4.	PB selection	*Barkhe*2027	M1BM98-S15M99-BM00-BMO1	IPB plot # 15	R	R	MR
5.	PB selection	*Barkhe* 2019	M1BM98-S6M99-BM00-BMO1	IPB plot # 6 (1-6)	R	R	MS
6.	KIII/IR-64	*Barkhe* 1029	F3SC98-LDBM99-BM00-BM01	Late Dwarf (s)	R	R	MR
7.	PB selection	*Barkhe*1005	M1BM98-S92M99-BM00-BM01	IPB plot # 92 (4-10)	R	R	MS
8.	PB selection	Sugandha-1	M1BM98-S39M99-BM00-BMO1	IPB plot # 39	R	R	MR

BLB = Bacterial Leaf Blight, PB = Pusa Basmati-1, IPB = Irradiated Pusa Basmati-1, KIII = Kalinga III, R = Resistant, S = Susceptible, MR Moderately Resistant, MS = Moderately Susceptible.

4.9 Post-harvest Evaluations

The agronomic performance of superior genotypes was assessed jointly by plant breeders and farmers. The participating farmers assessed the post-harvest traits and organoleptic taste of superior bulks. The micromilling test of grain quality, and the organoleptic taste assessment, have been found efficient in screening out poor rice lines and avoided wasting resources on field testing lines that farmers would, in any case, later reject.

In 2000, out of 57 lines evaluated for post-harvest traits more than half could be rejected. A total of 27 were rejected (16 from micromilling and 11 from organoleptic taste assessment) for their colour, cooking and eating quality. The results showed that post-harvest evaluation is an important step in identifying PPB lines that would be preferred by the farmers.

5 Outputs

5.1 Varietal Diversity in HPPSs increased

The high potential production systems (HPPSs) of rice have very diverse biophysical and socio-economic environments, but there is a lack of rice varieties matching this diversity. A number of advanced breeding lines have recently been developed to match diverse production systems within HPPSs (Annex 1).

Through PPB, suitable varieties for diverse rice-producing environments can be developed in high potential production systems. Farmers' preference of PPB varieties over existing local cultivars, indicates that PPB will increase the varietal diversity in HPPSs.

It is noteworthy that a wide cross between Kalinga III and IR64 produced genotypes that farmers preferred for the *Chaite* season (both for upland and irrigated environments) as well as for the main season (for upland, optimum and long standing water conditions). One reason for this success is the method of participatory testing employed. If a cross is aimed at developing varieties for diverse production environments, the breeding lines should be tested in those environments. In conventional breeding systems, a breeder handles large number of crosses with a very limited area under each entry, and most screening is done in the optimum production system, with less consideration for other, less favourable production environments. Conversely, PPB maximised the exploitation of G x E interactions by testing plants across a range of production environments in the HPPSs, and in a range of farmer management regimes.

5.2 Methods for PPB in high potential production systems.

Pedigree, modified bulk and equal seed descent (ESD) breeding methods have all been employed. the pedigree breeding technique requires more resources and breeders' time to maintain progeny rows and make selections for desired plant types than bulk or ESD methods. Moreover, because the heritability of yield and yield components are also very low in segregating generations for pedigree breeding, the extensive resources spent on selection in early generations in pedigree breeding methods is less effective.

The modified bulk and ESD methods are easy to use and were efficient in extracting superior genotypes from the crosses, with fewer resources and greater farmer participation than the pedigree breeding method. Detailed experiments comparing different breeding methods will be undertaken in a second phase of the project.

One of the important outputs of the project is that from only three crosses[†] several superior genotypes have been derived from each of them for diverse environments. This supports our hypothesis that a low cross number and high-population breeding strategy works well for self-pollinated crops (Witcombe *et al.*, 2001).

5.3 Micromilling and Organoleptic Taste Assessment as Selection Criteria

Testing rice lines for milling traits, and farmers' involvement in organoleptic taste assessment helped identify farmers' preferred varieties. It was a cost-effective way of screening out undesirable lines.

6 Contribution of Outputs

The output of the project in HPPSs will directly contribute to the DFID development goals. PPB in HPPSs has been successful in generating diverse breeding lines suitable for different production environments with variations in crop duration, adaptation to different input levels, and tolerance to a range of abiotic and biotic stresses. Furthermore, partnerships with CBOs, NARC and DOA have been established during the project period to transfer the knowledge and skills of researchers, as well as disseminate PPB output to the stakeholders.

(a) What further market studies need to be done?

The micromilling and organoleptic tests conducted in the project have provided important information for the potential acceptability of PPB lines in different parts of Nepal.

(b) How the output will be made available to intended users?

- PPB products will be multiplied and scaled up for wider adoption. LI-BIRD is in the process of developing a partnership with DOA and its district network. The verified materials will be scaled up through the DOA network across the *terai* and foothills of Nepal.

- LI-BIRD is working closely with NARC in different collaborative research projects. LI-BIRD has signed a letter of agreement with NRRP to seek its support for PPB, including testing and integration of the products of PPB into the national system. NRRP Hardinath has already tested PPB materials for disease resistance. There is a mutual sharing of PPB experience and genetic materials with NRRP through close collaboration.
- Crosses between carefully selected parents can produce highly variable populations from which farmers' preferred genotypes could be extracted through appropriate selection in target environments (Witcombe and Virk, 2001). The result that low cross number and high population size are effective for PPB in HPPSs will be disseminated through collaborative activities with DOA/Nepal and

[†] There were seven in total but in four of them it is not yet theoretically possible to have produced varieties as they are still segregating

NARC, through the presentation of results in workshop/symposia, and through the publication of journal articles.

- The outputs of PPB rice in HPPSs have already started influencing CBOs, NGOs and line agencies outside the project areas. There is a growing demand for seed of superior PPB lines by farmers, CBOs, DADOs, NGOs/INGOs and NRRP.

(c) What further stages will be needed to develop, test and establish the manufacture of products?

Crop breeding is very time consuming and a three-year period is insufficient to develop varieties and reach valid conclusions. A vigorous dissemination programme is needed so that as many farm families as possible, in different districts of Nepal, can benefit from the new rice varieties. LI-BIRD has already begun this process, and will be working jointly during the coming season with nine out of 21 *terai* districts to scale up the outputs of PCI and PPB. There is scope for extending this initiative in more districts in the *terai*, and possibly in low hill areas as well.

(d) How and by whom, will the further stages be carried out and paid for?

The second phase of the PPB/HPPSs project has been approved and started, funded by the DFID Plant Sciences Research Programme, UK. The second phase of the project will consist mainly of activities for verification of PPB process and products.

7 Acknowledgements

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Farmers of Chitwan district, who were the key players in the implementation of this project, are sincerely acknowledged for their continued cooperation and for contributing to the research process by providing land and valuable feedback.

Similarly, we are thankful for the cooperation of the National Rice Research Program, Hardinath and District Agriculture Development Office, Chitwan.

8 Publications

Joshi, K. D., Sthapit, B. R., Subedi, M., and Witcombe, J.R., (2001). Experience of participatory plant breeding in Nepal. In: *Farmers, Scientists and Plant Breeding: Integrating Knowledge and Practice*, David A. Cleveland and Daniela Soleri. (eds.) CABI (in press).

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Annex 1. Advanced breeding lines, crosses, target environments and breeding methods used in PPB/HPPSs program in Chitwan by 2001.

SN	Crosses	Name of Lines	Target Environments	Breeding Method
Lines of KIII/IR64 for *Chaite* season				
1	K III/IR64	*Judi* 101	Upland (C)	Pure line from modified bulk
2	K III/IR64	*Judi* 102 †	Upland (C)	MB
3	K III/IR64	*Judi* 111	Upland (C)	MB
4	K III/IR64	*Judi* 115 †	Medium Upland (C/M)	MB
5	K III/IR64	*Judi* 503 †	Medium Upland (C/M)	Pure line from modified bulk
6	K III/IR-64	*Judi* 506 †	Medium Upland (C)	Pure line from modified bulk
7	K III/IR-64	*Judi* 521 †	Medium Upland (C/M)	MB
8	K III/IR-64	*Judi* 523	Medium Upland (C/M)	Ashoka MB PPB 00C (Indian)
9	K III/IR-64	*Judi* 524	Medium Upland (C)	Pure line from modified bulk
Lines of KIII/IR64 for *Barkhe*/ Main season				
10	K III/IR64	*Barkhe* 1002	Upland (M)	Pure line from modified bulk
11	K III/IR64	*Barkhe* 1004	Medium Upland (M)	Pure line from modified bulk
12	K III/IR64	*Barkhe* 1012	Medium Upland (M)	Pure line from modified bulk
13	KIII/IR64	*Barkhe* 1027 †	Upland/ Medium Upland (U)	Pure line from modified bulk
14	K III/IR64	*Barkhe* 1029	Medium Upland (M)	Pure line from modified bulk
15	K III/IR64	*Barkhe* 2003	Medium lowland (M)	Pure line from modified bulk
16	K III/IR64	*Barkhe* 2007	Medium lowland (M)	Pure line from modified bulk
17	K III/IR64	*Barkhe* 2012	Medium lowland (M)	Pure line from modified bulk
18	K III/IR64	*Barkhe* 2014	Medium lowland (M)	Pure line from modified bulk
19	K III/IR64	*Barkhe* 3004 †	Low land (M)	Pure line from modified bulk
20	K III/IR64	*Barkhe* 3005	Low land (M)	Pure line from modified bulk
21	K III/IR64	*Barkhe* 3006	Low land (M)	Pure line from modified bulk
22	K III/IR64	*Barkhe* 3007	Low land (M)	Pure line from modified bulk
23	K III/IR64	*Barkhe* 3008	Low land (M)	Pure line from modified bulk
24	K III/IR64	*Barkhe* 3010 †	Low land (M)	Pure line from modified bulk
Lines of Irradiated Pusa Basmati-1 (IPB)				
25	IPB	*Barkhe* 1005 †	Medium Upland (M)	Pure line from modified bulk
26	IPB	*Barkhe* 1006	Medium Upland (M)	Pure line from modified bulk
27	IPB	Sugandha-1 †	Medium Upland (M)	Pure line from modified bulk
28	IPB	*Barkhe* 2001 †	Medium lowland (M)	Pure line from modified bulk
29	IPB	*Barkhe* 2002	Medium lowland (M)	Pure line from modified bulk
30	IPB	*Barkhe* 2006	Medium lowland (M)	Pure line from modified bulk
31	IPB	*Barkhe* 2019	Medium lowland (M)	Pure line from modified bulk
32	IPB	*Barkhe* 2020	Medium lowland (M)	Pure line from modified bulk
33	IPB	*Barkhe* 2022	Medium lowland (M)	Pure line from modified bulk
34	IPB	*Barkhe* 2023	Medium lowland (M)	Pure line from modified bulk
35	IPB	*Barkhe* 2024	Medium lowland (M)	Pure line from modified bulk
36	IPB	*Barkhe* 2025	Medium lowland (M)	Pure line from modified bulk
37	IPB	*Barkhe* 2026 †	Medium lowland (M)	Pure line from modified bulk

Annex 1 Continued

Annex 1 (continued)

SN	Crosses	Name of Lines	Target Environments	Breeding Method used

38	IPB	*Barkhe* 2027	Medium lowland (M)	Pure line from modified bulk
39	IPB	*Barkhe* 2034 †	Medium lowland (M)	Pure line from modified bulk
40	IPB	*Barkhe* 2035 †	Medium lowland (M)	Pure line from modified bulk
41	IPB	*Barkhe* 2041	Medium lowland (M)	Pure line from modified bulk
42	IPB	*Barkhe* 3009 †	Lowland (M)	Pure line from modified bulk
Lines of Radha 32/KIII				
43	Radha 32/KIII	Plot # 2	Lowland (C)	Pure line from modified bulk
44	Radha 32/KIII	Plot # 6	Lowland (C)	Pure line from modified bulk
45	Radha 32/KIII	Plot # 10	Lowland (C)	Pure line from modified bulk
45	Radha 32/KIII	Plot # 16	Lowland (C)	Pure line from modified bulk
47	Radha 32/KIII	Plot # 18	Lowland (C)	Pure line from modified bulk
48	Radha 32/KIII	Plot # 20	Lowland (C)	Pure line from modified bulk
49	Radha 32/KIII	Plot # 23	Lowland (C)	Pure line from modified bulk
50	Radha 32/KIII	Plot # 32	Lowland (C)	Pure line from modified bulk
51	Radha 32/KIII	Plot # 35	Lowland (C)	Pure line from modified bulk
52	Radha 32/KIII	Plot # 39	Lowland (C)	Pure line from modified bulk
53	Radha 32/KIII	Plot # 42	Lowland (C)	Pure line from modified bulk
54	Radha 32/KIII	Plot # 44	Lowland (C)	Pure line from modified bulk
55	Radha 32/KIII	Plot # 45	Lowland (C)	Pure line from modified bulk
56	Radha 32/KIII	Plot # 53	Lowland (C)	Pure line from modified bulk
57	Radha 32/KIII	Plot # 54	Lowland (C)	Pure line from modified bulk
58	Radha 32/KIII	Plot # 56	Lowland (C)	Pure line from modified bulk
59	Radha 32/KIII	Plot # 58	Lowland (C)	Pure line from modified bulk
60	Radha 32/KIII	Plot # 60	Lowland (C)	Pure line from modified bulk
61	Radha 32/KIII	Plot # 63	Lowland (C)	Pure line from modified bulk
62	Radha 32/KIII	Plot # 65	Lowland (C)	Pure line from modified bulk
63	Radha 32/KIII	Plot # 69	Lowland (C)	Pure line from modified bulk
64	Radha 32/KIII	Plot # 73	Lowland (C)	Pure line from modified bulk
65	Radha 32/KIII	Plot # 74	Lowland (C)	Pure line from modified bulk
66	Radha 32/KIII	Plot # 75	Lowland (C)	Pure line from modified bulk
67	Radha 32/KIII	Plot # 82	Lowland (C)	Pure line from modified bulk
68	Radha 32/KIII	Plot # 83	Lowland (C)	Pure line from modified bulk
69	Radha 32/KIII	Plot # 85	Lowland (C)	Pure line from modified bulk
70	Radha 32/KIII	Plot # 94	Lowland (C)	Pure line from modified bulk
71	Radha 32/KIII	Plot # 96	Lowland (C)	Pure line from modified bulk
72	Radha 32/KIII	Plot # 161 †	Lowland (C)	Pure line from modified bulk

C = *Chaite* season, M = Main (*Barkhe*) season, C/M = Targeted for both *Chaite* and Main season, KIII = Kalinga III, MB = Modified Bulk, † = Line preferred by farmers from PPB villages.

Annex 2. Advanced PPB lines included in the seed multiplication and generation advance in *Barkhe* and winter season rice in 2001.

SN	Name of Breeding Lines	Target Environments	Seed Multiplication/ Generation Advance
UPLAND/ MEDIUM UPLAND			
1	*Judi* 111	Upland	Seed Multiplication
2	*Judi* 521	Upland	Seed Multiplication
3	Sugandha-1	Medium Upland	Seed Multiplication
4	*Barkhe* 1002	Medium Upland	Seed Multiplication
5	*Barkhe* 1004	Medium Upland	Seed Multiplication
6	*Barkhe* 1005	Medium Upland	Seed Multiplication
7	*Barkhe* 1006	Medium Upland	Seed Multiplication
8	*Barkhe* 1012	Medium Upland	Seed Multiplication
9	*Barkhe* 1027 (K-III×IR64)	Upland	Seed Multiplication
10	*Barkhe* 1029	Medium Upland	Seed Multiplication
IRRIGTED/ OPTIMUM CONDITION			
11	*Barkhe* 2001	Medium Lowland Low land	Seed Multiplication
12	*Barkhe* 2006	Medium Lowland Low land	Seed Multiplication
13	*Barkhe* 2014	Medium Lowland Low land	Seed Multiplication
14	*Barkhe* 2019	Medium Lowland Low land	Seed Multiplication
15	*Barkhe* 2026	Medium Lowland Low land	Seed Multiplication
16	*Barkhe* 2027	Medium Lowland Low land	Seed Multiplication
LONG STANDING WATER CONDITION			
17	*Barkhe* 3001	Lowland Low land	Seed Multiplication
18	*Barkhe* 3004 (KIII/IR-64)	Lowland Low land	Seed Multiplication
19	*Barkhe* 3009 (IPB)	Lowland Low land	Seed Multiplication
20	*Barkhe* 3010 (KIII/IR-64)	Lowland Low land	Seed Multiplication
GENERATION ADVANCE			
21	Radha 32/KIII Plot # 6		
22	Radha 32/KIII Plot # 10		
23	Radha 32/KIII Plot # 39		
24	Radha 32/KIII Plot # 74		
25	Radha 32/KIII Plot # 161		
26	KIII/IR64 Plot # 20		
27	KIII/IR64 Plot # 53		
28	KIII/IR64 Plot # 85		
29	KIII/IR64 Plot # 94		
30	KIII/IR64 Plot # 96		
SEGREGATING LINES			
31	Masuli/IR64 F_2- F_3		
32	Masuli/MT4 F_3- F_4		
33	Pusa Basmati-1/Jetho Budho (ESD population) F_4- F_5		
34	Pusa Basmati-1/Jetho Budho (Modified Bulk population) F_4- F_5		

KIII = Kalinga III, ESD = Equal Seed Descent, IPB = Irradiated Pusa Basmati-1