Department For International Development
P*lant* S*ciences* R*esearch* P*rogramme*

FINAL TECHNICAL REPORT

R Number: R8099

Short Title: Participatory plant breeding in rice and maize in eastern India

Project Leader: D.S. Virk

Period: 1st February 2002 – 31st March 2006

Executive Summary

The project purpose was 'participatory methods for varietal selection and breeding developed, tested, piloted and promoted in the semi-arid production system'. The project targeted poor and marginal farmers in eastern India (Jharkhand, W. Bengal and Orissa) who grow old and low yielding landraces because of lack of suitable modern varieties. The project sought to breed new varieties of rice and maize using client-oriented breeding. .

New varieties released and in pipeline
Two varieties of upland rice Ashoka 200F, Ashoka 228 and one of maize (BVM 2) were released by the Birsa Agricultural University in 2003 and later notified by Government of India in 2005. The two rice varieties have also been recommended in Rajasthan and MP and are being tested in Gujarat and Tamil Nadu.

Two varieties of upland rice (Komal 6 and Richa 5) and two of maize (BVM 5 and BVM 6) were identified BAU for proposing for release .

In addition, 5 varieties of transplanted rice (A165, A900F, Sugandha-1, Barkhe 3010 and Judi 578) have been identified to be farmer-preferred and are in the advanced stages of testing. Seven varieties of maize are also in the advanced stages of testing and, of these, three are in the final stages of testing in the All India Coordinated Testing system.

This is the first known report where marker assisted selection programme for root QTLs have led to the development of farmer-preferred varieties. Richa 5, incorporating aroma and root QTL is highly preferred by upland rice growers. Pyramid lines such as PY 83, PY 84 and P157 and P170 with root QTLs are very promising for direct seeding in the upland and medium lands.

Community based seed production
Our surveys indicated that about 33% area of rice in West Bengal, 38% in Jharkhand and 41% in Orissa is upland in the project areas. However, farmers have poor seed supply. The project mobilised 16 self-help groups in Orissa and Jharkhand to produce seed of rice varieties. Pending notification of PPB bred varieties farmers produced truthful seed. The seed produced in 2002-03 was 39 t that rose to 81 tonnes in 2003-04 and is expected to be nearly 300 t of certified seed in 2005-06. Foundation and breeder seeds were also produced in 2005. Demand for the seed of upland rice varieties is huge and an independent consultant documented a demand for 690 t.

Wider dissemination
The seed produced by communities was widely dissemination through, GOs, NGOs and private companies all over India. For example, seed given to Catholic Relief Services was distributed seed to 5000 farmers in 2004 and 2005.

Efficiency of breeding methods
Are PPB varieties genetically more variable was addressed by comparing the intra-varietal variation of varieties developed by bulk breeding and line breeding from the same cross. Intra-varietal variation for quantitative traits was low and 43 SSR markers showed more variation in the bulk-selected varieties than the line bred varieties. However, all varieties met the criteria of DUS required for seed production.

Comparisons between pedigree, bulk and single seed descent methods were also made.

Impact studies
Seed flow among farmers was documented and farmers adopted the new varieties on 8 to 63% of the upland areas as recorded in one of the surveys. Farmers replaced their landraces for new varieties because they did not have to trade-off for many good traits in the new varieties. Farmers liked them for higher yield, good grain quality, better drought tolerance and earlier maturity.

The adoption of new varieties improved the food security of households from an average of 7 months to 10 months. The average rice selling ability of a household improved from 34 kg to 80 kg per year. Nearly 80% households reported more than 10% improvement in their income after growing new varieties.

The financial analysis with conservative assumptions revealed a net benefit of about £300 m by 2014 which is much higher than the total expenditure incurred on PSP.

Contributions towards PSP-DFID's goals
The PSP-DFID goal, 'Livelihoods of poor people improved through sustainably enhanced production and productivity of RNR systems' was addressed by the project and the provision of new seeds to poor farmers in eastern India improved their livelihoods and food security significantly by the EOP.

Background

The project built on the outputs of PSP funded project R7434 (Oct. 1999 to July 2002), 'Innovative methods for rice breeding — combining participatory plant breeding (PPB) with molecular marker techniques'. The project aimed at providing new drought tolerant varieties to poor farmers who grew old and unproductive landraces because of lack of suitable varieties in rice and maize. In R7434, breeding materials with farmer-preferred traits were generated both in rice and maize. In rice, two types of materials were in advanced stages: 1) from straight crosses between upland and irrigated varieties, and 2) that had QTLs for root growth and drought resistance traits introduced into Kalinga III from Azucena by back crossing and using marker assisted selection (MAS). By the end of R7434 two new upland rice varieties (Ashoka 200F and Ashoka 228), and one maize variety (BVM 2) had been identified by PPB for scaling up and release in Jharkhand.

R8099 sought to scale up the outputs of R7434, both horizontally and vertically, and to develop new farmer preferred varieties in rice and maize.

Horizontal scaling up was aimed to promote the geographical spread of varieties to more primary beneficiaries by facilitating formal and informal seed production and dissemination. This was to involve *Krishi Vigyan Kendras* (Farm Science Centres), State Seed Corporations, NGOs, private seed companies, and seed producing groups of farmers. New varieties were aimed to be tested in trials of the Indian Council of Agricultural Research, State Agricultural Universities and Departments of Agriculture for official release.

Vertical scaling up aimed at involving institutional spread from grassroots to policymakers, donors, and development institutions. The project also targeted to disseminate internationally the knowledge gained, and target key institutions and attempt to change mindsets by organising exposure visits, training courses, and symposia.

The results of collaborative and consultative PPB undertaken in R7434 are not yet fully evaluated. A comparison of the relative efficiencies of PPB and traditional breeding approaches was to be made, and selection by farmers in segregating bulks and farmer-to-farmer spread monitored. Variability within PPB varieties needed to be quantified, and varieties improved by selecting superior genotypes within them.

Project purpose

Participatory methods for varietal selection and breeding developed, tested, piloted and promoted in the semi-arid production system.

The project purpose addressed the identified constraints and opportunity to development in R7434 where poor farmers did not have enough choice of new varieties and the seed availability was constrained. New client-oriented varieties were bred, tested and identified through participatory methods. Community-based seed production was started and seed supply of new varieties improved.

Methods of participatory plant breeding were standardised for use in the semi-arid production systems.

Activities

Output 1: Demand and seed supply system for upland rice varieties determined

1.1 Analysis of GVT(E) survey reports
1.2 Compile and analyse official statistics
1.3 Examine usefulness of ICRISAT GIS survey data
The specified activities were modified to meet the indicators: comparative data on cultivation statistics in 4 ecosystems of rice available by 2003 and data on seed supply system in GVT (E) available by 2003.

A survey was conducted in 2003, through GVT (E), on 1287 farmers in Jharkhand, West Bengal and Orissa to document the area under the four ecosystems of rice.

Mr A. Bourai of Sri Guru Ram Rai College Dehradun conducted a survey in December 2003 to study the seed supply and impact of two upland rice varieties developed in the project. Two surveys by Mr P.D. Smith of CAZS-NR, in November-December 2004 and August 2005, documented seed demand, supply and impact of Ashoka varieties.

These surveys achieved the indicators specified. No official records for the four ecosystems were available in the newly created state of Jharkhand and thus the specified activity had to be modified. Similarly, GIS maps from ICRISAT could not studied but the project was linked to R7541 so that rice fallow lands in eastern India are better used by growing the short duration rice varieties bred in the project followed by *rabi* cropping on residual moisture.

Output 2: Products of PPB widely promoted

The knowledge, process and products of PPB to be widely promoted.

2.1 Multiply and distribute PPB varieties widely:
Community based seed production of PPB varieties of rice, i.e., Ashoka 200F and Ashoka 228 was undertaken in all years and seed production has been increased to about 300 t in 2005-06 winter season. All seed produced was ‘truthful’ seed pending notification of varieties till 2005. Breeder, foundation and certified seed production were started in 2005. However, seed production of BVM 2 variety of maize has lagged behind and in 2002-03 only 5 t of seed was produced by farmers.

Seed of PPB varieties was made available to SAUs, State Departments of Agriculture, seed agents, KVKs and NGOs in the GVT(E) area for promotion.

2.2 Widely test PPB varieties

Seed of PPB products was made available to SAUs, National Agricultural Research Institutes, Departments of Agriculture, Krishi Vigyan Kendras, private seed companies and NGOs for testing and for spread beyond the GVT(E) area. Thousands of farmers were given the seed of new varieties both in the project area and outside of project area that included the DFID bilateral project in western India (GVT west). Seed of Ashoka varieties was given to other SAUs such as Indira Gandhi Agricultural University, Raipur and Tamil Nadu Agricultural Univeristy for testing.

New PPB products in rice and maize were tested in the All Coordinated Projects of ICAR, state trials by SAUs and on-farm trials by GVT.

2.3 Introduce and test PPB varieties from Nepal:

PPB products from LI-BIRD (R7122 and R8071) were imported for testing in the medium- and lowlands. Three entries (Sugandha-1, Judi 578 and Barkhe 3010) have been identified as promising and are being tested in participatory on-farm trials, state trials and All India Coordinated Rice Improvement Project of ICAR.

2.4 Propose most accepted varieties for official release:

Release proposals of 2 varieties in rice and 2 in maize are being prepared.

Output 3. Efficiency of PPB methods enhanced

3.1 Monitor farmers' selections n bulks:

Several segregating bulks provided to farmers were monitored, and farmer's selections were compared to the checks in trials. Six segregating bulks from marker assisted selection programme were given to farmers in three states and pure lines have been extracted from the selected bulks by farmers.

Several bulks of segregating advanced trials for transplanted conditions were also provided to farmers for selection.

3.2 Compare PPB (collaborative and consultative) and traditional methods of breeding:

A comparison of the efficiency of methods of breeding was made in the advanced generations of two crosses, i.e., Vandana/ IR72975 and RRU 95001/A200F. Trials were conducted to compare the efficiency of pedigree, bulk and single seed descent methods in 2005. Data are being analysed for computing comparative estimates of genetic advance from different methods.

3.3 Monitor changes in gene frequencies in selected bulks by MES:

This was partly achieved by monitoring the gene frequencies in the marker assisted selection bulks where significant reduction in QTL frequency was found in the on-farm selections by farmers. However, gene frequencies in farmers' selected bulks in a cross and marker-evaluated selection for the most useful genomic regions for marker-assisted selection could not be accomplished.

3.4 Genetic variability in PPB varieties evaluated:

Extensive trials were conducted in 2003-04 winter, 2004 main season and 2005 main season to evaluate intra-varietal variation in varieties developed by mass selection in segregating bulks (A 200F and A 900F) and by line breeding (A 228 and checks, Kalinga III and IR64). Also pure lines from the varieties were evaluated for 44 SSR markers. Intra-varietal variation irrespective of the method was low and all varieties qualified for DUS test. Thus varieties produced using client-oriented breeding are as homogeneous as developed by traditional methods.

Output 4: PPB methodology widely disseminated

4.1. Knowledge gained during the project period and most appropriate breeding approach disseminated through visits, workshops and publications

For vertical scaling up of PPB methodology, institutional spread from grassroots to policymakers, donors, development institutions, was a priority. Nine papers were published in peer-reviewed journals and 22 papers were presented in national and international symposia/workshops. These papers were as follows:

- 3 papers in IRRI/PSP Conference 12-15 March, 2002, Manilla; 1 paper in Hallauer Symposium 17-22 August, 2003, Mexico; 3 papers in Rockefeller Foundation Workshop, 24 to 28 May, 2004 in Mexico; 1 paper in Rockefeller Foundation Workshop, 23-25 July 2003, Bangalore, India; 3 papers in Inter-drought-II conference, 24-28 September 2005, Rome, Italy; 6 papers in National Conference on increasing rice production under water limited environment, 3-4 December 2004, Ranchi, India; 2 papers in National Seminar on advanced Genetics and Plant Breeding, 30-31 October 2003, Dharwad, India; 1 paper in the Annual Session of National Academy of Sciences, India, 10-12 October 2003, Ahmedabad, India; 1 paper in the 9th Asian Regional Maize Workshop, 5-9 September 2005, Beijing, China; 1 paper in the Brainstorming Session of the Trust for Advancement of Agricultural Sciences, 7-8 January 2005, New Delhi, India.

Dissemination by training workshops

- Dissemination of methods across projects was made by organizing and participating in the training and review meetings of CIMMYT-CAZS project on wheat PVS in Kathmandu, Nepal from 8-14 July 2002, 10-14 June 2003, and 14-18 June 2004. These presentations targeted participants from India, Nepal and Bangladesh.
- Training workshops in PPB were organized for participants from Ethiopia in Nepal (29 April to 11 May, 2004) and further two in-country trainings were given in Ethiopia in January-February 2005. Lectures on participatory techniques were given in Ethiopia in March 2004 and June 2005.
- Trainings in participatory seed production were given to seed producing farmers in Orissa every year.

Some progress has been made on institutionalising participatory approaches in BAU. Participatory data were used in variety release proposals, and variety releasing procedures were accelerated for the PPB varieties.

Additional output 5: Impact assessment of PPB varieties

Four surveys by independent consultants and one by PI and project staff were conducted to assess the spread and impact of Ashoka varieties on the livelihoods of farmers. These surveys were:

1. Mr V. Bourai of Department of Economics, Sri Guru Ram Rai College, Dehradun, India, Dec 2002.
2. Dr Andrea Mottram of CAZS-NR, University of Wales, Bangor, UK, October 2004.
3. Mr Paul Smith of CAZS-NR, University of Wales, Bangor, UK, Nov/Dec 2004 and Aug 2005.
4. D.S. Virk of CAZS-NR and project staff to study the landrace replacement with new varieties, March 2004.

Additional output 6: PVS and PPB in horsegram

Horsegram was found to be an important late rainy season crop in the area. Therefore horsegram was included in the activities and PVS on varieties collected from different regions was conducted with farmers for 3 years.

A mutation breeding programme combined with PPB was started and two entries in the M3 generation were found to be promising. These were tested in station trials and All-India Coordinated Programme (BAUK 2 and BAUK 3) in 2005.

Outputs

Products and the outputs of the project can be grouped into: (1) Demand and seed supply for upland rice varieties determined, (2) products of PPB widely promoted, (3) efficiency of PPB methods enhanced, and (4) PPB methodology widely disseminated.

Output 1: Demand and seed supply system for upland rice varieties determined.

Indicators

- Comparative data on cultivation statistics in 4 ecosystems of rice available by 2003.
- Data on seed supply system in GVT(E) available by 2003.

Progress

To assess the comparative importance of four ecosystems of rice GVT E was contracted to conduct a survey in both GVT and non-GVT villages in three states. The survey was conducted after the harvest of rice in three states in 2003. The major objectives were: to examine the land holding, extent of rainfed agriculture, cropping patterns and areas under rice, maize and wheat crops, areas of upland (rainfed bunded or unbunded *tanr* land of farmers that forms the top-land of farmers' fields), medium land and lowland rice, patterns of use of rice fallows, varietal portfolio of farmers and source of seed availability.

A questionnaire was used to collect the data in three states Jharkhand, W. Bengal, Orissa. The number of farmers interviewed was 1287 (Table 1).

Table 1. Detail of survey conducted by GVT

State	No. of districts	No. of GVT villages	No. of non-GVT villages	No. of farmers
Jharkhand	4	12	13	250
W. Bengal	2	6	6	627
Orissa	3	29	5	410

Main conclusions were:

- The majority of farmers have small landholding of less than 2 ha.
- The average proportion of rice area classified as upland, in both project non-project villages in the study districts, was 33% in West Bengal, 38% in Jharkhand and 41% in Orissa.
- The majority of upland (93% in Orissa, 84% in W. Bengal and 85% in Jharkhand) remained fallow after rice.

Mr P.D. Smith in Nov/Dec 2004 and August 2005 conducted two studies to document seed supply system of Ashoka varieties of rice.

Survey of Nov/Dec 2004

Survey with seed producing groups and prospective seed traders and NGO Mr Smith identified a demand of over 690t. However, he recommended that GVT should produce at least 250 t of Ashoka varieties for distribution in 2005 rainy season. The proportion should be 50 to 60% of Ashoka 228 and 40 to 50% of Ashoka 200F. He also recommended that given the level of interest, a minimum of 500 t should be produced in 2006. Some of the other observations were:

- There are 0.7 million ha of upland rice in Jharkhand which is 40% of the total rice growing area in the state and 10% of the upland rice area in the whole of India.
- In farmer's fields, Ashoka varieties provide a 50 to 300% yield advantage over local varieties. In research plots the advantage is in the range of 20 to 50%. Yields are typically 2.5 to 3 tonnes per ha under rainfed conditions and around 4 tonnes per ha under irrigated conditions.
- Over 150 varieties of upland rice have been released in India since independence. However, none is in seed production and out of 1200 t seed requirement of upland varieties in Jharkhand the government could only procure 100 t in 2005. No private seed companies are producing upland rice varieties, as it is not sufficiently profitable. Thus there is a huge seed supply gap for the upland varieties that are grown by poor farmers.
- Most (90%) Ashoka seed has been produced by 8 Self-Help Groups in Dhenkanal (4 SHGs), Kheonjar (3 SHGs) and Kalajhini (1 SHG) in Orissa State under contract to GVT.
- As Ashoka varieties are not notified their certified seed cannot be produced. Thus Truthfully Labelled (TL) Seed should be produced.
- Demand for seed of Ashoka varieties was collected from 3 GO, 2 NGO and 3 private companies in Jharkhand; from 2 NGOs in MP; from 1 NGO each in UP, Chhatishgarh and Orissa; from 3 NGOs and 7 private companies in West Bengal.

Survey of August 2005

- Many farmers plant Ashoka varieties in medium land either by broadcasting or by growing in nurseries and transplanting. This means that Ashoka varieties have a broad adaptability.
- About 7 ha of Ashokas were planted in Jharkhand and Orissa in 2005 main season for the production of foundation seed. He predicted about 333 t certified seed production in the winter season of 2005-06 for distribution and sale to farmers for the main season of 2006.

Output 2: Products of PPB widely promoted

Indicators

- Partnership established in 3 states with private seed sector and farmer seed groups, KVKs, Dept. of agriculture. At least 5 PPB rice and 2 maize varieties widely promoted by EOP.
- At least 2 rice and one maize varieties proposed for release by 2005.

- By 2005 at least 2 PPB varieties adopted outside of GVT East area in India or Nepal.

Progress

Release of varieties

Two varieties of rice: Ashoka 200F and Ashoka 228 developed through client-oriented breeding were formally released in Jharkhand in May 2003. One variety of maize, BVM 2, was also formally released in Jharkhand in May 2003. All these varieties were however notified by Government of India for seed production in 2005. Thus no certified seed could be produced prior to 2005.

More varieties of rice and maize are in the pipeline (see later).

Community-based seed production of rice varieties

Non-notification of rice and maize varieties by Government of India constrained certified seed production. Therefore, for wider dissemination of rice varieties self-help groups of GVT were mobilized to produce 'Truthful seed'. Sixteen self-help groups in Dhenkanal and Mayrubhanj districts of Orissa have been producing seed in the off-season (winter) since 2001-02. Farmers in Jharkhand were mobilized to produce 74 t of 'Foundation' seed in the main season of 2005 for use in the Certified seed production in the winter season of 2005-06 in Orissa. The community-based seed production has increased over years (Fig. 1).

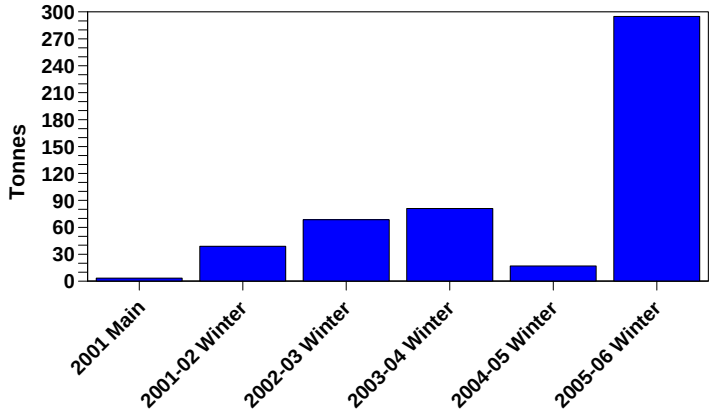


Fig. 1. Community based seed production of two rice varieties (tonnes) by GVT east from 2001 to 2005-06

Two private seed producers from Jharkhand were mobilized in the rainy season of 2001 to produce about 3 t of seed of rice varieties. However none of them continued the seed production in the subsequent years because of low profit margin in the seed production of upland rice varieties, particularly in the kharif season since the seed has to be stored for a long-term. However, they preferred to buy seed produced by GVT farmers for further selling in other areas.

Partnerships for seed dissemination

The seed of two rice varieties was distributed very widely to thousands of farmers by establishing partnership with a number of NGOs in three states through GVT channels and other PSP funded projects. In 2004, Catholic Relief Services (an NGO) alone distributed seed to 5000 farmers in 2 kg seed packets in Chhattisgarh, MP and Jharkhand. Linkages with Western Orissa Livelihood Project of DFID were also established by providing them the seed. The seed was distributed widely through:

- State Coordinators of GVT in Orissa, W. Bengal and Jharkhand.
- A number of NGOs through GVT's State Coordinators
- Private seed agents particularly in Ranchi
- Department of Agriculture of Jharkhand, W. Bengal and Orissa (especially the worse drought areas of Kalahandi and Bolangir districts).
- State Agricultural Universities in Jharkhand, Tamil Nadu, and Karnataka (Dharwad)
- Government agencies such as Jharkhand Tribal Development Society.

About 10 t seed of rice varieties was also provided to GVT West in 2002 for distribution in MP, Rajasthan and Gujarat. The performance of the two rice varieties was excellent, and the GVT West has now started its own community-based seed production and is producing 100s of tonnes of seed for a large-scale distribution.

Mr P.D. Smith was requested to assess demand of Ashoka varieties in November/December 2004. He listed 7 private seed merchants and many NGOs who demanded large quantities of seed for selling in the three states. Also a number of NGOs outside GVT area demanded seed, e.g., ASA in MP. The total seed demand from all sectors in 2005 rainy season was estimated to be 686 t. However, the quantity of seed being produced by the GVT in the off-season of 2004-05 was far less (20 t).

Meeting such a huge demand for seed in the future is a challenge. The following may be useful:

1. Encouraging the seed producer groups in Orissa to continue seed production as a commercial activity.
2. Mobilizing some private companies to enter into seed production. They would only take up seed production if they had known the performance of varieties with farmers. If the private sector is provided a large quantity of seed in 2006 they will have sufficient feedback from farmers for the varieties, and may take up seed production in 2007.
3. Linking the seed production activity to the Rockefeller Foundation project (2005 to 2009) that will strengthen private-public seed sector collaboration.

Adoption of project varieties in other states

Two varieties of rice, i.e., Ashoka 200F and Ashoka 228 are well adapted to all drought prone areas in India. On-farm trials conducted by various agencies have shown that these varieties have been adopted by farmers outside the GVT east area such as: MP, Rajasthan

and Gujarat (as reported by GVT West, ASA and CRS), Tamil Nadu Agricultural University, Dharwad Agricultural University in Karnataka (Rockefeller Foundation meeting, 22 to 28 May 2004, Mexico), and in MP, Jharkhand and Chhattishgarh by CRS.

Variety A200F has been recommended by Rajasthan and Gujarat and both A200F an A228 by MP for general cultivation in rainfed uplands. These varieties are also being tested for release in Tamil Nadu.

Seed production of maize varieties

Seed production of maize has been limited primarily due to lack of interest of Birsa Agricultural University, which controlled Breeder seed production. Farmer groups in W. Bengal took up seed production of variety BVM 2 in 2002-03 winter season and about 5 t seed was produced that was disseminated in the GVT villages.

Wide testing of client-oriented breeding products

Varieties bred through client-oriented breeding in rice and maize were widely tested by contributing entries in the All India Coordinated Improvement Project trials through out India (Table 2). A number of varieties, particularly in maize performed well in the trials and are in the third year of testing for the release at state or national level.

Two varieties of horsegram bred through mutation breeding combined with client-oriented breeding were entered in the All India Coordinated testing as BAUK-2 (20 kR treatment) and BAUK-3 (30 kR treatment).

Three varieties of chickpea: Birsa Channa-1 and Birsa Channa-2 (pea shape) for the late sown trials and Birsa Channa-3 (desi type) for the normal sown are being tested in All India Chickpea Trials in 2005-06.

Varieties in pipeline

Several varieties of rice are in the advanced stages of testing or release and are being disseminated.

- Upland: Richa 5, Richa 6, PY 83, PY 84, P167 and P170 from marker assisted selection for root QTL. Komal 6 and Komal 9 from client oriented breeding. A number lines from many crosses are also in the advanced stages of testing.
- Medium land transplanted conditions: Ashoka 165, Ashoka 900F, and a number of varieties from Nepal such as Barkhe 3010, Judi 578 and Sugandha-1. In addition, a number of advanced materials are very promising.
- Several maize varieties as given in Table 2.

For the wider testing and dissemination of pipeline varieties for transplanted conditions a large-scale seed production (1 to 2 t) for each of 5 varieties (Sugandha-1, Barkhe 3010, Judi 578 from Nepal, and Ashoka 165 and Ashoka 900F bred in India) was undertaken in the off-season of 2004-05 in Orissa. In the 2005 main season seed of all the 5 varieties was widely distributed in the project area through GVT to hundreds of farmers who preferred them to their local checks.

Table 2. Varieties of rice and maize bred in the project and contributed to the all India Coordinated Project testing from 2002 to 2004

Crop	2002		2003		2004		2005	
	Entry	**Trial**	**Entry**	**Trial**	**Entry**	**Trial**	**Entry**	**Trial**
Rice	Bulk 2	IVT E	*Bulk 6*[†]	*IVT E*	Bulk5	IVT E	Bulk 6	IVT E
	Komal 6	IVT E	*Komal 9*	*IVT E*	Judi 578	IVTMEI	PY 84	IVT E
			A 900F	*IVT MEI*	Sugandha-1	IVTMEI	A165	IVTMEI
							A900F	IVTMEI
Maize								
	BVM2	AET2	BVM7	IET Extra early	BVM7	AET-1 Extra early	BVM7	AET-2
	BVM2	IET Baby corn	BVM4	IET Extra early	BVM4-1	IET Early	BVM4-1	AET-1
	BVM4	IET Early	BVM5	IET Early	BVM5	AET-1 Early	BVM5	AET-2
			BVM6	IET Early	BVM6	AET-1 Early	BVM6	AET-2
			BVM7	IET QPM 2	BVM8	IET Early	BVM7	IET Extra Early
					BVM8	IET Extra Early	BVM7	IET QPM-1
							BVM8	AET-1
							BVM9	IET Early
							BVM9	IET Extra Early
							BVM10	IET Early

[†] Italics show planned entries whose seed was not sent by Birsa Agricultural University, Ranchi.

Release of more varieties

During 2005, varieties Komal 6 and Richa 5 of upland rice and BVM 5 and BVM 6 varieties of maize developed in the project were proposed for release but their release was postponed by BAU for one year for testing in the formal zonal trials. However, they are spreading from farmer-to-farmer.

The 5 pipeline varieties of rice and several varieties of maize have already completed three years of testing in research and on-farm trials and are ready for release by BAU. A number of maize varieties have completed three years of testing in the All India Trials and are due for consideration for all India release in the Annual Workshop to be held in April 2006.

Linkages

Linkages of R8099 with R8221 have been created to combine their outputs in growing a rabi crop on residual moisture following the earlier maturing rice varieties in the main season.

Linkages have been established with Indira Gandhi Agricultural University, Raipur in Chhatishgarh where the upland rice varieties are being tested for release.

Linkages with CRS have helped in wider dissemination in MP.

Output 3: Efficiency of PPB methods enhanced

Indicators

- By EOP data available on modes and extent of farmer collaboration in two methods and two crosses.
- By EOP, MES data available for one cross.
- Extent of intra-cultivar diversity in two PPB rice varieties determined by 2003.

Progress

Collaborative mode of participation was used in a number of crosses in rice but the consultative mode was not done by BAU and GVT because of changes in staff in BAU and changes in the priorities of GVT. The rice crosses selected by farmers in collaborative mode in different generations over years were as follows:

Direct seeded upland ecosystem
F5 of PSBRC78/A228
F5 of PSBRC78/Komal 13
F6 of Cross 1010 (Vandana x IR72)
F6 of Cross 1011(Vandana x IR72975)
F4 of CAZSR 02011 (RRU 95001/A200F)
F4 of CAZSR 02020 (CT6510/Barkhe 2027)-rejected

Transplanted rice
F4 and F5 of IR64/PB1
F4 and F5 of Pusa44/IR64
F4 and F5 of IR64/PR111
F4 and F5 of IR64/PR114
F5 of PR114/IR65
F5 of PR114/IR66
F5 of PR114/IR67
F5 of PR114/IR68
F5 of PR114/IR69
F5 of PR114/IR70
F5 of PR114/IR71
F5 of PR114/IR72

From the farmer selected bulks of segregating generations hundreds of pure lines were extracted and evaluated in station trials in 2005. These need to be tested by farmers in the future PVS programmes.

In maize, only consultative mode of participation was used due to the cross-pollinated nature of the crop. Trials on the extent of cyclic improvement by mass selection by farmers were conducted and the data are yet to be analyzed.

Several entries from the collaborative breeding in rice and consultative mode in maize have already been included in the national trial system of ICAR and state trials. It is yet to be seen how these varieties perform across a larger geographic area. However, in maize the evidence is overwhelming since a number of varieties are in the final stages of evaluation and release (Table 2).

Comparison of breeding methods

The efficiency of breeding methods was quantified, and compared to conventional methods by using 'a few cross' and 'large population' approach. Comparison was made between pedigree, SSD and bulk methods using two crosses:

- F_5 and F_6 of CAZSR 02011 (RRU 95001/A200F); 140 lines from each method were drawn for comparison
- F_7 and F_8 of Cross 1011(Vandana x IR72975); 100 lines were drawn from each method of breeding

Trials were conducted in the main season of 2005 to compare different methods of breeding. Several promising lines from the two crosses are already being tested in the national and state trial systems. Future performance of these entries will establish the comparative effectiveness of PPB methods for institutionalization.

Marker evaluated data from a cross

A comparison of changes in gene frequencies in the farmers' and breeders' selected bulks (marker evaluated selection) was intended to establish the most useful genomic regions that can be exploited in marker-assisted selection (MAS) combined with PPB. This could not be taken up fully due to the setup problems of partners in India. However, gene frequencies were monitored in the 6 MAS bulks and it was found that the frequencies of root QTL and aroma QTL in farmer selected Bulk 5 decreased considerably. This could be due to selection by faemers for plants with most insect resistance since those with aroma QTL were found to be susceptible to insect attack.

Diversity within Ashoka varieties and comparison of breeding methods

PPB varieties are thought to be genetically more variable than traditional varieties. We compared intra-varietal variation of two rice varieties (Ashoka 200F and Ashoka 900F) produced by a very simple bulk breeding method (mass selection with no line selection at any stage) with one line-selected variety (Ashoka 228), all derived from the same cross. Their parents, the upland variety Kalinga III and the irrigated transplanted medium-lowland variety IR64, both originated through line-selection and were used as control varieties.

Panicle-to-row progenies of all the varieties were evaluated under irrigation in the dry season and in the rainy season using two water regimes; entirely rainfed or with supplementary irrigation. Intra-varietal variation for quantitative traits, irrespective of the method of breeding, was low. Only Ashoka 200F had significant variation for grain yield, days to flowering and plant height but only in the dry season. This season was not the target of the breeding programme and selection would be unlikely to produce a worthwhile response for the rainy season.

At 43 SSR loci there was more genetic variation between lines within the bulk-selected varieties than within Ashoka 228. Kalinga III was the least variable variety while IR64 had less heterozygosity but greater heterogeneity than the two bulk-selected varieties.

Despite the greater simplicity of the method, mass-selection in bulk populations produced varieties that met the distinctness, uniformity and stability (DUS) criteria for seed certification. We conclude that this very simple bulk-population breeding approach is highly cost-effective and produces sufficient seed for wide testing earlier than any alternative method.

Output 4: PPB methodology widely disseminated

Indicators

- At least 3 papers published by 2005.
- At least 3 visits and 3 training workshops organized by 2005.

Progress

Paper publications

- More than 5 peer-reviewed papers have been published in international journals (see list).

Dissemination in workshops/symposia/conferences

- 22 papers were presented in various workshops/conferences/symposia to disseminate PPB methodology.

Additional output 5: Impact assessment of PPB varieties

Four surveys were conducted to assess the spread and impact of Ashoka varieties on livelihoods of farmers. The main findings were:

- Though recommended for direct seeding in uplands, Ashoka varieties are also successfully grown by farmers in medium land usually under transplanted conditions. This is more so in poor rainfall years which are 3 or 4 years out of 10.
- Between 10 to 100 % farmers who took part in seed production in the winter season retained some seed for the main season crop.
- In villages where seed had been disseminated, between 50 and 100% of the farmers who had grown Ashoka in 2004, retained seed for planting in 2005. In many cases, although the number of households had decreased due to low rainfall, the average planted area had increased.
- Average production by farmers under rainfed conditions was mostly in the range of 0.99 to 1.23 t ha^{-1}. However, in some communities the average production was over 2.47 t ha^{-1}.
- ***Example of seed flow:*** Seed flow of Ashoka varieties through the New Adibasi SHG (a women's group, the male members of their families help with ploughing) in Ranipur village of Purulia district, W. Bengal in 2003 and 2004 is summarised

in Figure 2. The connection with Balarampur was that the mother of one of the key group members, Badani Tudu, lives there.

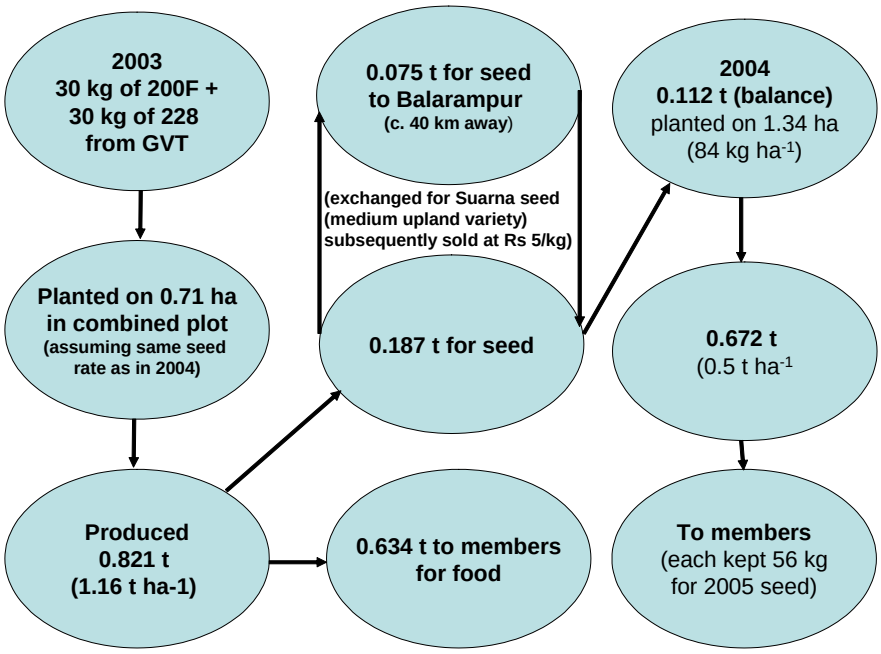


Figure 2. Distribution of seed within New Adibasi SHG from P.D. Smith's report

Figure 3. Male group of farmers completing preference rankings of local and Ashoka upland rice varieties, and female group discussing preference ranking with extension agents, Kalajhini, Mayurbhanj district, Orissa, October 2004 survey by Dr A. Mottram.

Adoption of Ashoka varieties

Adoption studies of Ashoka varieties were conducted by A. Mottram in the GVT adopted villages (Fig. 3). Adoption rates of Ashoka 228 and Ashoka 200F were calculated for 11 villages where seed had been distributed for at least two years. The adoption rates varied from 8 to 63% of the upland rice area (Fig. 4). In just two to three years since the introduction of Ashoka seed, on average 30±6% of the upland rice previously cultivated,

has been replaced with Ashoka 228 or Ashoka 200F. The variation in adoption was largely dependent on the amount and number of farmers that seed had been distributed to by GVT in previous years.

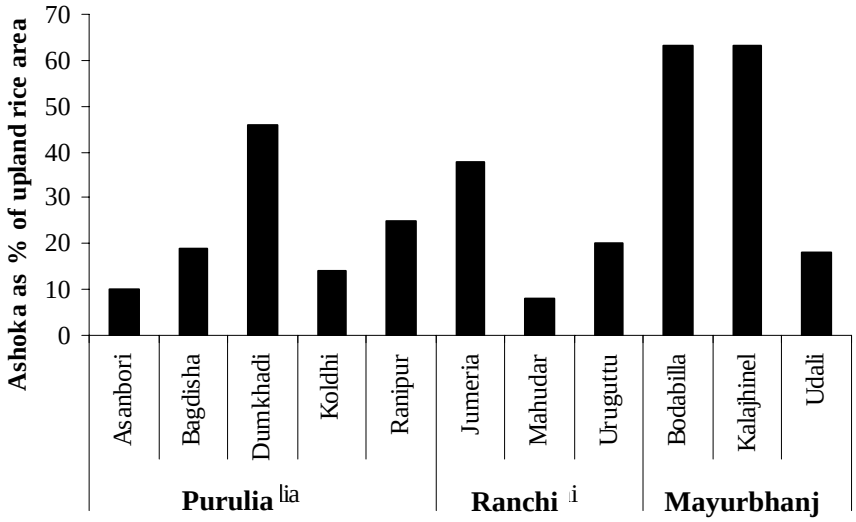


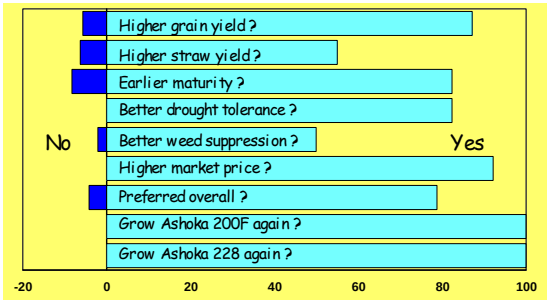
Figure 4. Adoption levels of Ashoka expressed as percentage of upland rice area, in *kharif* season 2004 from a survey in October 2004 survey by Dr A. Mottram.

Why farmers prefer the new varieties?

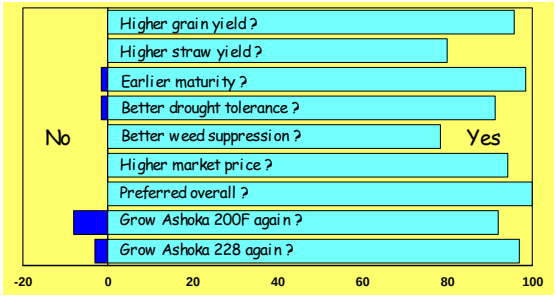
In the surveys conducted by Mr Bourai, the majority of farmers in all three states perceived that, compared with local cultivars, the new varieties were, higher yielding and more resistant to lodging, and had many other favourable traits (Fig. 5). These slender-grained varieties were easier to market and fetched a higher grain price than the local, coarse-grained varieties.

Effect on livelihoods

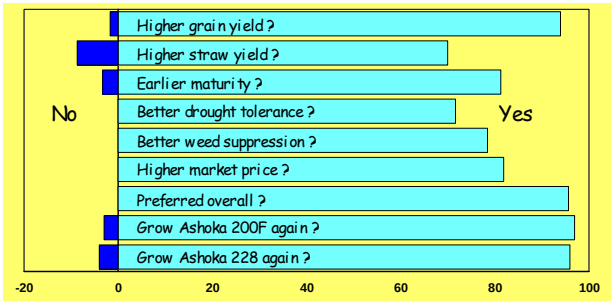
During surveys by A. Mottram, farmers reported that the benefits of cultivating Ashoka have had a major impact on their livelihoods (Fig. 6). They said that food is available in years of poor rainfall and during the lean periods of the year, and straw is available for fodder earlier in the season. Additional 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.



Corresponding farmers (%) in Orissa, n = 38



Corresponding farmers (%)in W. Bengal, n = 45



Corresponding farmers (%) in Jharkhand, n = 76

Figure 5. Farmers' perception (expressed as % of farmers) for Ashoka 228 and Ashoka 200F rice varieties in comparison to the local cultivars. Based on a survey of 159 households sampled over all three states (Orissa, Jarkhand, West Bengal). December 2002.

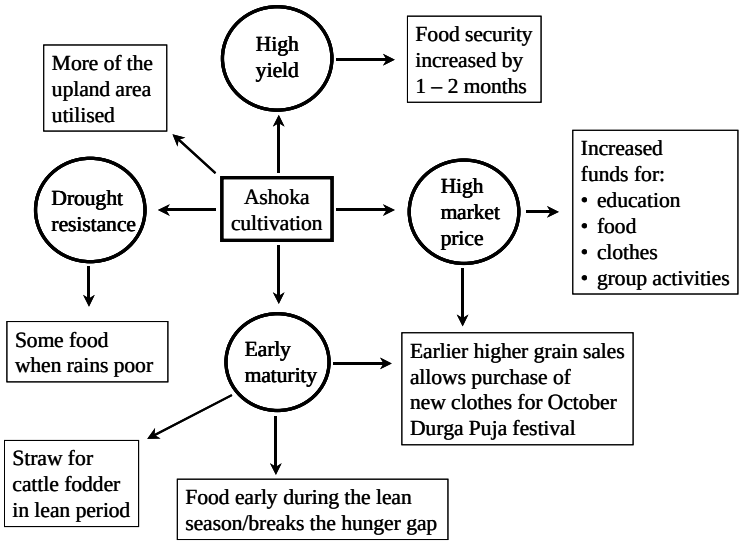


Figure 6. Diagram of the effects cultivating Ashoka can have on farmers' livelihoods, as determined in farmer group discussions. The diagram is a summary of group responses from 14 villages in three districts, October 2004 survey by A. Mottram.

A survey in 2004 showed that there was an increase in food security by 36% and an increase of 137% in the rice sold by the individual households in eastern India (Table 3). 80% of farming households perceived more than 10% improvement in their livelihoods from cultivation of Ashoka varieties (Table 4).

Table 3. Impact of new varieties of rice varieties on food security and of households sold and how long rice lasted in the HH

State	N	Rice sold		Consumption period	
		Before introduction (kg)	After Introduction (kg)	Before introduction (month)	After Introduction (month
Jharkhand	57	0.93	10.45	6.14	10.26
W. Bengal	60	45.00	59.92	7.93	9.67
Orissa	33	70.21	237.88[§]	8.67	10.52
Wtd Aver.	150	33.80	80.27	7.41	10.08

[§]Seed production was taken in Orissa so the seed sale is higher.

Table 4. Impact on livelihood (% improvement)

State	N	<10%	10-20%	20-30%	30-40%	>40%
Jharkhand	57	11	52	32	5	0
W. Bengal	60	22	45	17	10	6
Orissa	33	24	36	24	6	9
Overall	150	19	44	24	7	5

Financial analysis

A preliminary financial analysis based on the survey conducted by Mr Bourai (using the conservative assumptions in the box below) has been made of the benefits of these varieties in three states: Jharkhand, Orissa and West Bengal (Fig. 7; Bourai *et al*., 2002; Virk *et al.*, 2003a). The benefits are large and anticipated cumulative benefits from this project by 2010 will be far greater than the total expenditure of £19.5 million on the Plant Sciences Research Programme from 1995-2005 and will equal the total expenditure on the RNRRS by 2011.

The benefit/cost ratio of this research is very favourable, even assuming a higher than actual annual cost of research of £100,000. The benefits of this research have to be shared between the RNR Research Strategy and the DFID India desk, as donors, and between CAZS, GVT and BAU as the project implementers. The benefits are sufficiently substantial for this credit sharing.

The Ashoka varieties are very well accepted compared to the traditional landraces or other modern varieties making predictions on their adoption more reliable. In addition, their superior performance under drought greatly reduces the uncertainty of the forecasts on their impact.

Assumptions

- In all three states, a rate of increase in area of about 3.0 times per year following an S-shaped adoption curve.
- An adoption ceiling of 50% of the non-irrigated rice areas of 0.42 million (m) ha in Jharkhand, 3.0 m ha in West Bengal and 2.6 m ha in Orissa.
- An increased benefit per hectare from Ashoka 200F and Ashoka 228 of £33 per hectare (500 kg additional yield at £0.09 kg^{-1}).
- GVT supplies seed sufficient to sow 1600 ha in the first three years (the actual amount for 2002 and the planned amounts for 2003 and 2004). In 2005 this halves to 800 ha, in 2006 it halves again to 400 ha and remains constant until 2010 when seed supply is assumed to stop.
- An annual cost of £100,000 for research and development.

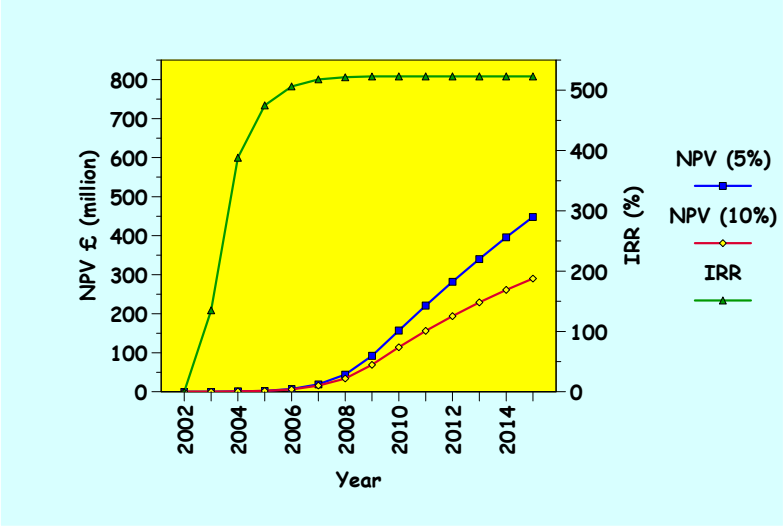


Figure 7. **Net present value (NPV) and internal rate of return (IRR) over time from the new rice varieties using the assumptions described in the box above.**

These assumptions are conservative on the seed supply side. If the project continues to supply seed to farmers in the same amounts beyond 2004, then these very substantial benefits increase still further. Moreover, the two varieties have been officially released but no account has been made of official seed production by government or other agencies in Jharkhand and elsewhere.

This scenario ignores four additional likely impacts from:

- The adoption of Ashoka 200F and Ashoka 228 in western India (Rajasthan, Gujarat, Madhya Pradesh) that is expected to be substantial (see box).
- The adoption of these varieties on other states in Eastern India, such as Bihar and Chhattisgarh (formerly eastern Madhya Pradesh).
- The adoption of other varieties adapted to medium land conditions, such as Ashoka 900F that are likely to raise the adoption ceiling above 50% of the dryland area.

- The likely partial replacement of Ashoka 200F and Ashoka 228 with superior varieties that are emerging from the participatory plant breeding programme in eastern India.
- The impact of varieties introduced from DFID-PSP supported PPB programmes in Nepal. For example, variety Sughandha-1 from the Nepal programme is performing well in medium uplands in eastern India.

Additional output 6: PVS and PPB in horsegram

Horsegram is an important late rainy season crop in the area. Therefore PVS on varieties collected from different regions in India was conducted with farmers for 3 years. The results have shown that a released variety BK 1 was the highest yielding in all years (1.13 t ha^{-1}) but farmers wanted an earlier maturing variety because of frequent drought years. Farmers preferred VLG 1, an earlier maturing variety (84 days, 10 days earlier than BK 1) with a mean yield of 0.94 t ha^{-1}.

A PPB programme was undertaken by subjecting BK 1 to mutation treatments with gamma rays. Two entries from mutation breeding programme are being tested in All-India Coordinated Programme (BAUK 2 and BAUK 3).

However, seed production is a major constraint in popularization of horsegram varieties.

Contribution of Outputs to Project Goal

The outputs achieved contribute greatly to the project goal as methods of client-oriented breeding have been successfully employed and standardised and new varieties of rice and maize bred, tested, released and promoted with farmers and other organisations. Seed availability of farmers has been improved and made sustainable by promoting community-based seed production. Livelihoods of poor farmers of rainfed uplands have been improved and 80% farmers recorded more than 10% increase in their incomes. Food security of deficit farmers increased form 7 to 10 months in a year.

What further market studies need to be done?
Accetability evaluation of some pipeline varieties of rice for transplanted situations by processing industry need to be made.

How the ouputs will be made available to intended users?
Seed production is a major constrain. Community based seed production of Ashoka varieties will help in their spread. However, for the newly identified farmer-preferred varieties the spread to intended users will be very slow.

What further stages will be needed to develop, test and establish manufacture of a product?
Products in the pipeline need to be further tested in on-farm and on-station trials till they are released or widely disseminated, i.e., at least for 2 –3 years.

How and by whom, will the further stages be carried out and paid for?
Testing in further stages will be highly constrained without further funding till the products are owned by the NARS.

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