A REVIEW OF BHUTAN'S RICE RESEARCH PROGRAM WITH EMPHASIS ON THE LOW ALTITUDE ZONE

Edwin L. Javier, Consultant

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Executive Summary

The average total rice area and production in Bhutan are 18,885 ha and 60,995 t, respectively, for 2004 and 2005 cropping seasons. The generally productive mid and high altitude zones occupy around 62% of total rice area and contribute some 67% to the total production. The generally unfavorable low altitude zone covers around 39% of the total area but contributes only 32% to the total production. Its mean yield is less than 0.57 t/ha compared to that of the mid altitude zone. Because of the large area that the low altitude zone occupies, even a modest increase in its productivity can have a good impact on overall domestic rice production. This review is commissioned to review the rice research program (accomplishments, production constraints, research gaps and opportunities) and identify ways to improve rice productivity in the low altitude zone and at the same time sustain the gains in the productive altitude zones

The investment in rice research for more than two decades has reaped substantial quantitative and qualitative gains in increasing rice productivity and livelihood of the rice farmers. The national self-sufficiency in domestic production has reached about 68% at the household level. Contributing to the success of the research program are the strong leadership of the RNRRC-Bajo which has the national mandate for formulating and implementing the national strategic objectives and research thrusts; strong collaboration among the major stakeholders (CoRRB, RNRCs, DoA, district extension units and farmers); partnership with relevant international/regional research organizations and donor institutions; pro-farmer legal instruments governing plant genetic resources and chemical-based agricultural inputs; among other things.

A review of research resources allocation has shown that varietal improvement research is the priority research thrusts. Improved varieties serve as the base from which other research components are built upon. The mid altitude zone varietal improvement research has the highest allocation of resources, with dry subtropical ecosystem getting more attention than the humid ecosystem. The high altitude zone research is a far second priority. The low altitude zone research has the least amount of resource allocation, particularly the unfavorable rainfed lowland environment which represents some 90% of the wetland in the southern belt.

Improved varieties and various crop management technology options have been disseminated all over the country. Released varieties and promising germplasm in the pipeline do not only have good yield potentials but also diverse genetic background. Some varieties have long life span, reflecting the breeders' successful system of selection. Most varieties selected under a particular altitude zone were planted not only in their selection environment but also in other altitudes, indicating the spill-over effect of research efforts from one zone to another zone. The nationwide adoption rate of released varieties is around 60%.

However, the adoption level has lagged behind at the low altitude zone where there are only two varietal options. Rice can now be cultivated in altitude between 2,500 to 2,800 m (Bumthang) because of improved varieties with cold tolerance. Around 500 land races have been conserved as well.

Technology recommendations being disseminated across altitude zones include the judicious use of commercial chemical inputs such as fertilizers, herbicide, and pesticides. Farmers who are willing to use the chemical options are confronted with input availability and cost. Some of them also have problems on availability of certified seeds. The constraint behind input supply and demand lies within the production/procurement-distribution chain composed of Druk Seed Corporation, commission agents, extension staff and farmers.

The uncertainty of the onset, amount, duration and distribution of rainfall that beset the unfavorable rainfed rice environment in the low altitude is the overriding factor that limits rice productivity. Analysis of the rainfall parameters indicate that rice production could commence as early as late May and the crop should be at the reproductive stage around September during which the probability of the recession of monsoon is high. The probability of drought is higher around October than September, thus the crop should be at ripening stage around October to escape drought in the absence of varietal resistance to drought.

In addition to drought, unpredictable rainfall regime in the south brings about a number of production constraints. Delayed monsoon aggravates the farm labor constraint. The heavy rainfall particularly during peak moon season causes landslides and floods that results in soil erosion that further impoverished the soil that is generally characterized by poor soil structure and texture; and damage the distribution channels/canals of the perennial and seasonal irrigation systems which serve as partial source of water for some farms. Extended late showers may take place after harvest and grain quality and milling recovery could be severely affected. Diseases and insect pests in the field and during seed storage also reduce yield and quality. Vertebrate pests like wild elephants, monkeys, wild boar, etc. are responsible for 47% yield reduction.

The economic impact assessment of the rice research program in Bhutan in the last two decades is the most notable contribution of the socio-economic and policy research thrust. It reveals the substantial contribution of rice research in increasing rice production and farm income. The rice research program has also been instrumental in building the country's capacity for rice research through infrastructure and manpower development. One of its major recommendations is to Increase research spending for the low altitude zone, where the marginal returns to additional investment is likely to be significant because of the large area involved.

Considering all of the above, the current review has come up with the following recommendations that aim to improve rice productivity in the low altitude zone and at the same time sustain the gains in the productive altitude zones. Rice varietal improvement should continue as the flagship component of the rice research program. The breeding program should focus on the following:

- allocating more resources for rainfed lowland varietal improvement research;
- expanding the germplasm acquisition from IRRI by including materials that would broaden the selection base for attributes desirable in rainfed lowland environment;
- breeding for modern varieties since introductions often do not have all the desirable attributes needed;
- incorporating farmer participatory plant breeding approach in varietal development;
- conducting screening for drought tolerance.
- defining clearly and prioritizing the desirable attributes that should be combined into a single variety;
- shifting some resources from the dry subtropical breeding program towards the less favorable humid subtropical program;
- expanding farmer participatory varietal selection to include varietal trials conducted in the research station;
- exploring selection among and within landraces to come up with purelines whose performance and uniformity could be even better than modern varieties under adverse environments; and
- sending to IRRI genebank duplicate samples of Bhutan's traditional varieties not yet deposited in IRRI for safe keeping.

The challenges for the other research thrusts are as follows:

- integrated nutrient management promoting pre-rice green manuring and developing fertilizer recommendations that are more site-specific.
- integrated pest management - monitoring closely emerging problems in the low altitude zone and possible second generation pest problems in the productive mid and high altitude areas.
- socio-economics and policy research – conducting in-depth study on factors that disrupts the flow of agricultural inputs from the primary source (Druk Seed Corporation) to the

end-users (farmers) via commission agents and extension personnel; enhanced role for the private sector on sale of agricultural inputs, farm labor; and farm credit.

- post harvest research – development/searching for affordable, economically efficient small dryers and milling equipment that would improve the quantity and quality of milled rice.
- agricultural engineering – alleviating the farm labor problem through the use of affordable simple machine and tools for labor intensive operations in the field and exploring water impounding techniques for the rainfed lowlands.

There are critical high level interventions that are essential for problems whose solutions are beyond the scope of research:

- assessing fully the existing irrigation systems in the southern belt, taking into consideration the flood-/landslide-damaged and unstable water channels, and possibility of constructing new channels to expand the number of households that will benefit from partial or full irrigation.
- finding ways to protect farmers' livelihood from vertebrate pests given the international and national commitment of Bhutan in biodiversity conservation.

Institutional collaboration is an important instrument in enhancing research output. There is a need for RNRRCs to forge strong collaboration with Agricultural Machinery Center and National Post Harvest Center for post harvest and lack of labor problems. Collaboration with Biodiversity Use and Conservation Asia Program for on-farm activities should be expanded to include sites in the unfavorable rainfed lowland areas. The strong linkage with IRRI should be maintained since it is still the major source of worldwide genetic variability for rice, new technologies, current literature, and opportunities for training and international workshops/conferences. The International Network for Genetic Evaluation of Rice, Consortium for unfavorable environment (CURE), and Rainfed lowland and upland rice drought-prone breeding program are the most relevant programs at IRRI. The rice research program should explore possible collaboration with the Paris-based *Centre de Cooperation Internationale en Recherche Agronomique pour le Développement* (CIRAD) which works in more than 50 countries worldwide on targeted research for developing countries. Communication with individual scientists at IRRI and those from other institutions with similar interests should continue.

To boost research in the rainfed rice environment, it is essential to strengthen the research capacity of Bhur Subcenter, the primary test location involved. There is an immediate need for more research staff, a screenhouse with a dark room for hybridization and rapid generation advance, vehicle and field/laboratory equipment in the subcenter. It is recommended that Mithun Subcenter be revitalized by adding new research staff to look after the research activities for the humid subtropical environment. It is also recommended that staff participating or to be involved in rainfed lowland and humid subtropical rice research should undergo short term training and study tours to improve their knowledge and skills.

A REVIEW OF BHUTAN'S RICE RESEARCH PROGRAM WITH EMPHASIS ON THE LOW ALTITUDE ZONE

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1. Introduction

Bhutan has an area of about 40,000 km^2 and a population of approximately 700,000. It is a landlocked country situated on the southeastern slope of the Himalayas (Figure 1). It has some 470-km border with China on the north and northwest and 605-km border with India's sates of Sikkim to the west, West Bengal to the southwest, Assam to the south and southeast and Arunachal Pradesh to the east (US Library of Congress). It has a rugged landscape consisting of mountains, valleys, ravines and depressions, drainage basins, fast-flowing rivers and water falls. Its elevation that ranges from 150 m to 7500 m is a major factor in its climatic diversity. The northern part of Bhutan is perennially covered with snow while the southern part is hot and humid with sub-tropical climate. Over 72% of the country is under forest cover. The cultivated area is about 8%, including wetland, dryland for horticulture crops and fallow rotation. About 79% of the people are living in rural areas.

Figure 1. Mountainous Bhutan is surrounded by China and India.

Rice is grown from tropical lowlands (200 m) in the south up to elevations as high as 2800 m in the north. Because of Bhutan's rugged topography, rice fields are generally terraced (Figure 2). Rice environments are broadly grouped into three altitude zones which also reflect different temperature regimes. The high altitude zone, also referred to as warm temperate zone, covers rice areas from 1,600 m and above. Low temperature at early vegetative stage of the rice crop characterizes this environment. Around 20% of the rice areas fall under this zone. The mid altitude zone which accounts for 40% of the rice areas has an elevation of 700 m to 1,500 m. Its sub-ecologies are the dry and humid sub-tropical environments, the latter receiving more rainfall than the former. The remaining 40% is the low altitude zone (200 m – 600 m) concentrated in the southern part of Bhutan and also referred to as the wet sub-tropical zone.

Bhutan is divided into 20 dzhongkhags or districts (Figure 3). The area grown to rice differed substantially among districts (Table 1). The total rice area grown to rice was 18,885 ha in 2004 to 25,295 ha in 2005, with a total rice production of 54,326 t and 67,607 t in the said years respectively. The average yield for the two years was 2.77 t/ha. Disregarding Bumthang which has a very small rice area, the district of Paro (t/ha) produced the highest yield (4.03 t/ha). It was followed by Wangdue, Punakha, Thimpu, Trashigang, Trashiyangtse, Mongar and Lhuntse, with yields of at least 3.00 t/ha. All districts are in the high and mid altitude zones. The low altitude districts comprise around 39% of the total rice area but contribute only 32% to the total rice production, indicating low productivity.

The low altitude zone is the least productive among the rice agroecological zones. Because of the sizeable area it occupies, even a modest increase in its productivity can have a good impact on overall rice production of the country. The major factors that are often mentioned to contribute to low production in the southern belt are the frequent occurrence of drought in its predominantly rainfed dependent lowland environment, poor soil conditions and high incidence of diseases, insect pests and vertebrate pests.

Rice research efforts in the past were concentrated in the favorable lowland rice environments in the mid and high altitude zones. Today, the national rice research program is committed to finding ways to improving rice productivity in the low altitude zone and at the same time sustaining the gains in the productive altitude zones. This consultancy is aimed at finding strategies to achieve this goal. The terms of reference of the consultant are as follows:

- Review past and current status of rice research, with particular focus on rainfed rice, and suggest improvement.
- Visit predominant rainfed rice growing areas in the southern part of the country for first-hand information on constrains and potentials.
- Visit RNR Research centers at Bajo and Bhur to discuss with relevant researchers to identify priorities and opportunities in rainfed rice

Figure 2. Rice terraces at Tsirang are typical in undulating terrain of Bhutan.

Figure 3. Bhutan is divided into 20 dzongkhags (districts).

Table 1. Rice production statistics by altitude zone and dzongkhag, 2004-2005.

Altitude zone/ Dzongkhag*	2004			2005			Mean		
	Area (ha)	Production (MT)	Yield (ha)	Area (ac)	Production (MT)	Yield (t/ha)	Area (ha)	Production (MT)	Yield (t/ha)
High altitude	**1951**	**7107**	**3.64**	**2381**	**9110**	**3.83**	**2166**	**8109**	**3.73**
Bumthang	3	11	3.88	18	74	4.06	11	43	3.97
Gasa	53	117	2.22	62	135	2.18	57	126	2.20
Haa	68	138	2.02	81	221	2.72	75	180	2.37
Paro	1211	4876	4.03	1487	5987	4.03	1349	5432	4.03
Thimpu	617	1965	3.19	732	2693	3.68	674	2329	3.43
Medium altitude	**9749**	**29432**	**3.02**	**13076**	**36728**	**2.81**	**11412**	**33080**	**2.91**
Chukha	518	1507	2.91	1439	3249	2.26	979	2378	2.58
Dagana	1379	2967	2.15	1633	3145	1.93	1506	3056	2.04
Lhuntse	519	1405	2.71	723	2397	3.31	621	1901	3.01
Mongar	533	1500	2.81	842	2805	3.33	688	2153	3.07
Pemagatshel	45	140	3.14	60	134	2.22	52	137	2.68
Punakha	1782	6906	3.88	1804	6915	3.83	1793	6911	3.85
Trashigang	1034	3913	3.79	1503	4297	2.86	1268	4105	3.32
Trashingtse	380	1257	3.31	771	2654	3.44	576	1956	3.37
Trongsa	656	1487	2.27	725	1658	2.29	690	1573	2.28
Tsirang	1195	2511	2.10	1685	3503	2.08	1440	3007	2.09
Wangdue	1267	4883	3.85	1350	4816	3.57	1308	4850	3.71
Zhemgang	442	956	2.16	541	1155	2.14	491	1056	2.15
Low altitude	**7185**	**17787**	**2.48**	**9838**	**21769**	**2.21**	**8512**	**19778**	**2.34**
Samdrupjongkhar	742	1385	1.87	1702	3911	2.30	1222	2648	2.08
Samtse	3352	6640	1.98	4801	9105	1.90	4077	7873	1.94
Sarpang	3091	9762	3.16	3335	8753	2.62	3213	9258	2.89
National	**18885**	**54326**	**2.88**	**25295**	**67607**	**2.67**	**22090**	**60967**	**2.77**

* The rice ecosystems in Bhutan are broadly categorized into three altitude zones and associated with particular dzongkhags. However, a dzongkhag may have one or more rice-altitude zones. The categorization of dzhogkhags into differernt altitude zones is based on the Eight Five-Year Plan for commodity programs.

Data source: Agriculture Statistics, 2005, Volume I.

- Identify gaps (technical, physical and manpower) in rice research and make recommendations for improvement.
- Identify potential regional and international institutions and networks particularly on rainfed rice to establish and strengthen contacts.
- Make specific recommendations on research strategies for rainfed rice research and development, including breeding program to improve rice production in rainfed environments.

2. Methodology for the review

The review was conducted using the information obtained through various ways. There were discussions with administrators, researchers and extension staff of the Council for Rice Research in Bhutan (CoRRB), Department of Agronomy (DoA), Renewable Natural Resources Research Centers (RNRRC)-Bajo, District Agriculture Offices at Samtse dzongkhag and Sarpang dzongkhag (districts), Kasadraphu experimental field of RNRRC-Yusipang, Darla Subcenter, Mithun Subcenter, and Bhur Subcenter. Field visits and discussions with farmers were conducted in the following geogs (blocks within dzongkhags):

- Samtse Dzongkhag: Samtse, Sipsoo, Biru, Changmary, Tendu, Ugyentse and village Vinchai
- Sarpang Dzongkhag: Biru, Dekaling, Hitley, Chhuzargang

A total of 21 farmers in the above geogs were interviewed to gain insights not only on their own experiences but also on those of their neighbors (Figure 4).

A number of documents were also reviewed, a list of which is given in the Reference section. The two most cited documents in this review are:

- An Economic Impact Assessment of the Rice Research Program in Bhutan (hereinafter referred to as impact assessment study) and
- Rainfed Lowland Rice Cultivation in Bhutan: A Survey Report (hereinafter referred to as 2003 survey report).

The first document is the source of 2002 survey data involving 248 households from 10 dhongkhags, of which 60 households were from Samtse (40) and Sarpang (20). The 2003 survey data revolved around 35 and 41 households in Samtse and Sarpang, respectively.

The International Rice Information system was used in getting information on germplasm exchange between the International rice Research Institute (IRRI) and RNRRC-Bajo, and genetic and passport data on released and promising varieties in Bhutan.


Figure 4. Farmers in Bawanggeon, Ugyentse (above) and Bhur (below) share their experiences on rice production under unfavorable rainfed lowland environment to the consultant and district extension staff of Samtse and Sarpang.

3. Rice production scenario

Rice is the staple food of at least 65% of the population. In the western and southern parts of Bhutan where it has been the traditional staple food, the per capita milled rice consumption ranges from 167 kg to 262 kg per annum. In areas where other crops have been the major calorie source, rice is now the preferred staple food. In urban areas, rice is also the preferred staple food. Domestic rice production does not meet the national requirement. The overall self-sufficiency level in domestic rice production is only about 68% of the households. The average rice import from 1995 to 2000 was about 33,000 t per year. Recently, the annual import amounts to more than 50,000 t. The demand for more rice is expected to increase over time. The major factors that contribute to this demand are the high population growth rate (2.5% per annum), increase in household income, and continuous migration to urban areas. The urban population, which represents 20% of the total population, is growing rapidly at a rate of at least 6% annually. Indeed, there is a need to increase domestic rice production.

In an impact assessment study conducted in 2002, the rice area decreased by around 9% mainly due to urbanization. However, production and average yield increased by at least 58% and 78%, respectively, during 1989 to 1997. This reflects the impact of research and development program of the country in the late 1970s up to the mid 1990s. The said period could be considered the green revolution era of Bhutan which focused on favorable environments. The national average yield of 2.77 t/ha based on 2004-05 data is 20% higher than the reported average of 2.30 t/ha during 1989-1997. This increase, however, was less than that obtained between 1989 and 1997. The impact of research and development efforts that focused mainly on favorable environments starts to show a diminishing return. Substantial gains may be achieved through innovative strategies for favorable environments and priority attention for less favorable ecosystems where improved technologies are needed.

4. Research structure and key players in national research and development program

The Council for Renewable Natural Resources of Bhutan (CoRRB) is a policy making-body that coordinates the national renewable natural resources research programs aimed at improving the overall productivity and sustainability of agriculture, horticulture, forestry and livestock enterprises. The research programs are implemented through four integrated Renewable Natural Resources Research Centers (RNRRCs). Each center has a national mandate for coordinating research in one of the four major sectors and a regional mandate to conduct research in sectors relevant to the assigned dzongkhags in its domain. The four centers and the dzongkhags within their geographical domains are as follows.

- RNRRC-Bajo at Wangduephodrang – covers the west central region composed of Wangduephodrang, Punakha, Gasa, Tsirang and Dagana;
- RNRRC-Yusipang at Thimpu – oversees the western region composed of Thimpu, Paro, Haa, Chukha and Samtse;
- RNRRC-Jakar at Bumthang – encompasses the east central region composed of Bumthang, Sarpang, Zhemgang and Trongsa; and
- RNRRC-Whengkhar at Mongar – watches over the eastern region consisting of Mongar, Lhuntse, Yangtse, Trashigang, Trashiyangtse, Pemagatshel and Samdrupjongkhar.

The RNRRC-Bajo has the national mandate for field crops research program, of which rice is a major component. The national rice research program is geared towards the development of rice-based technologies and related information to overcome production constraints to raise farm productivity for the benefits of rice farmers and consumers. The RNRRC-Bajo is the primary center for formulating the national strategic objectives and planning, managing and implementing the rice research program. To achieve these, it is ably supported by the other centers for region-specific concerns.

The rice research program has three agro-ecological zone oriented sub-programs, namely: mid, low and high altitude subprograms under the leadership of RNRRC-Bajo, RNRRC-Yusipang and RNRRC-Jakar, respectively. Each center has one or two subcenters in targeted environments to ensure the relevance of the research outputs. Each subprogram has three major discipline based research components:

- varietal improvement – germplasm conservation, varietal development, varietal testing, and seed production
- crop management – crop establishment, water management, nutrient management, pest management (weeds, insect pests, diseases, and astray animals), and post harvest management
- socio-economics and policy research (impact assessment and economics of rice production).

Each center has a multidisciplinary team of researchers for implementing the subprogram. RNRRC-Bajo, being the national center for rice research program, ensures that rice research in all centers support the national and regional priorities and provides technical guidance to other centers. It plays a lead role in international partnership and donor relations for rice research. It also facilitates the flow of germplasm from international and national rice programs and genebanks to all RNRRCs and their subcenters.

The Department of Agriculture (DoA) reigns the development component of the national rice program. It is mandated to plan, coordinate, administer, supervise and monitor the overall agriculture programs and RNR infrastructure growth to expand agricultural development in the country. Research is agroecological zone-based while DoA's extension system is district-based. Technologies generated in researcher-managed trials are validated in farmers' fields involving their own resources and management practices. The on-farm trials serve not only as the first step in technology dissemination but also as the vehicle for in-depth collaboration among researchers, extension officers and farmers. There are 20 District Agricultural Officers looking after the activities of around 200 extension staff assigned in various geogs of the country. An annual review and planning meeting participated by CoRRB, RNRRCs and DoA is held to ensure effective partnership between research and extension officers in generating and disseminating improved technologies.

5. Legal instruments governing plant genetic resources and chemical inputs

Before 1994, plant genetic resources were considered a common heritage of mankind. The free movement of plant genetic resources across national boundaries had been instrumental in the development of modern varieties that triggered the green revolution. Today, germplasm movement is governed by international agreements that a country is bound to implement and its national legislations.

In 1995, Bhutan became a Party to the Convention on Biological Diversity (CBD) which promotes the conservation of biodiversity, sustainable use of its components, and fair and equitable sharing of benefits derived from the use of genetic resources. However, it also restricts the movement of genetic resources for important crops like rice. In 2003, Bhutan became a Party to the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) which resolves the barriers imposed by the CBD on the global sharing of important food crop germplasm. ITPGRFA also promotes benefit sharing and recognizes farmers' rights. In 2003, it became a Party to the Cartagena Protocol which aims to protect biological diversity from the potential risk posed by living modified organisms resulting from modern biotechnology.

Important national legislations that have a bearing on varietal use and movement across national boundaries are already in place in Bhutan. The Biodiversity Act of 2003 has provisions on the rights of indigenous communities over traditional knowledge. The community based natural resources management projects of RNRRCs are in-support of the Biodiversity Act. The Biodiversity Act also has a chapter on *sui generis* system for the protection of plant varieties which answers the requirement of the Trade Related Aspects of the Intellectual Property Rights (TRIPS) agreement of the World Trade Organization. It includes farmers' rights and exemption for research purposes. This will encourage the entry of important protected varieties developed elsewhere that may be critical during unwanted calamities or disease epidemics. In 2000, Bhutan passed the Seeds Act that promotes the development and use of improved varieties and encourages the participation of the private sector and farmers' organizations in the seed industry. It created the National Seed Board, chaired by the Minister of Agriculture, which presides over varietal release and use.

The Pesticides Act of Bhutan that came into force in 2000 governs pesticide procurement and distribution. It ensures that integrated pest management is pursued, limiting the use of pesticides as the last resort and minimizing harmful effects on humans and the environment consequent to the application of pesticides, among other things. National Plant Protection Center plays a critical role in the implementation of the national integrated pest management program.

6. Rainfed lowland rice environments in Samtse and Sarpang

Samtse Dzongkhag and Sarpang Dzongkhag are both located in the southern foothills bordering India. The former has an area of about 1,582 km^2 with an altitude ranging from 600 m to 3,800 m above sea level (Department of Information and Technology, Bhutan, 2004-2005). The latter covers an area of 2,288 km^2 with an elevation ranging from 200 m to 3,600 m. Samtse has 16 geogs and 6,128 households while Sarpang has 15 geogs and 4,395 households. Being at the border of India, both districts serve as commercial centers. Rice is grown in altitude ranging from 300 m to 1,800 m.

The rainfall scenario at Bhur Sub-center, Bhur, Sarpang is described below. It is assumed to be a representative site in the southern foothills. The average annual rainfall varied from 1996 to 2006 (Figure 5). The average rainfall during the said period is 5,142 mm, with the lowest amount in 2006 (3,885 mm) and the highest in 2003 (7,160 mm). The monthly rainfall follows a unimodal distribution (Figure 6). The region receives 540 mm rainfall in May (541 mm) which is doubled in June and peaked in July (1,236 mm). The amount of rainfall declines sharply between September (635 mm) and October (256 mm). Only 5% of the total rainfall is received in October. Drought is frequently reported in October. The number of rainy days for each month also follows a unimodal distribution (Figure 7), with June, July and August having 24-26 rainy days. The mean number of rainy days in September is 18 while that of October is only 10. Based on the amount of rainfall and onset of rainy season, rice production could commence in late May. Monsoon starts receding around September and ideally the crop should be at reproductive stage to avoid the harsh effect of drought.

The statistics associated with mean monthly rainfall and number of rainy days are given in Table 2. The coefficient of variation would reflect the degree of reliability of occurrence of an event. A high value could indicate less dependable outcome. From May to September, the ranges of the coefficients of variation for rainfall and number of rainy days are 30.4%-42.3% and 11.9%-27.7%, respectively. This indicates that the rainfall condition is more reliable in this period than in other months. Considering the mean, ranges and coefficient of variation, the start of rainfed lowland rice cultivation could fall from late May to June. About 76% of farmers in the 2003 survey considered June as the start of the rainy season in the two districts. The same percentage of farmers identified August and early September as the end of the rainy season. This also agrees with the meteorological data. For rainfall, the mean is lower and the coefficient of variation is higher in October compared to that in September, indicating that October is more prone to drought than September. Ideally, the should be at ripening stage in October.

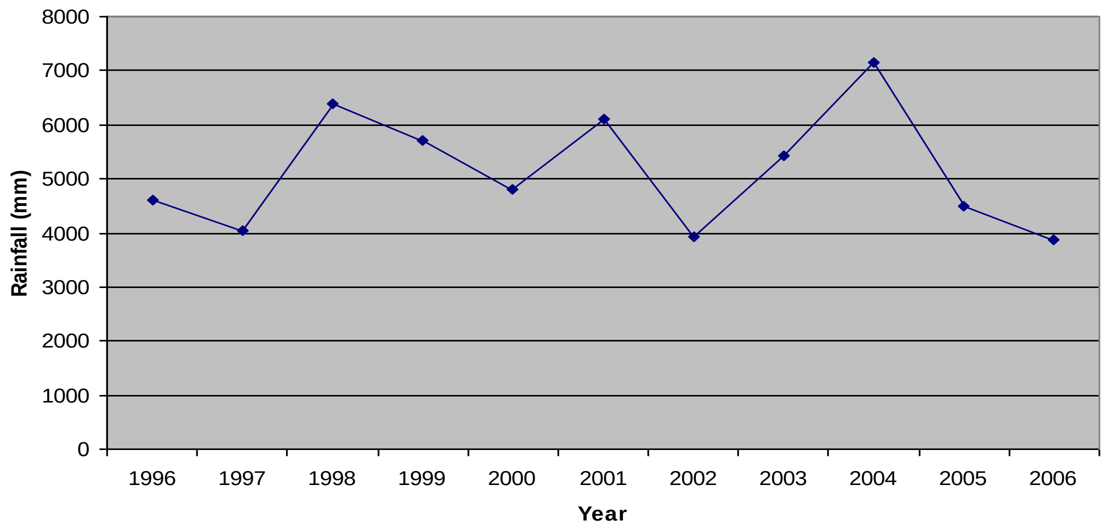

Fig 5. Mean annual rainfall (Bhur, 1996-2006)

Data source: Meteorology Section, Hydromet Services Division, Department of Energy, Bhutan

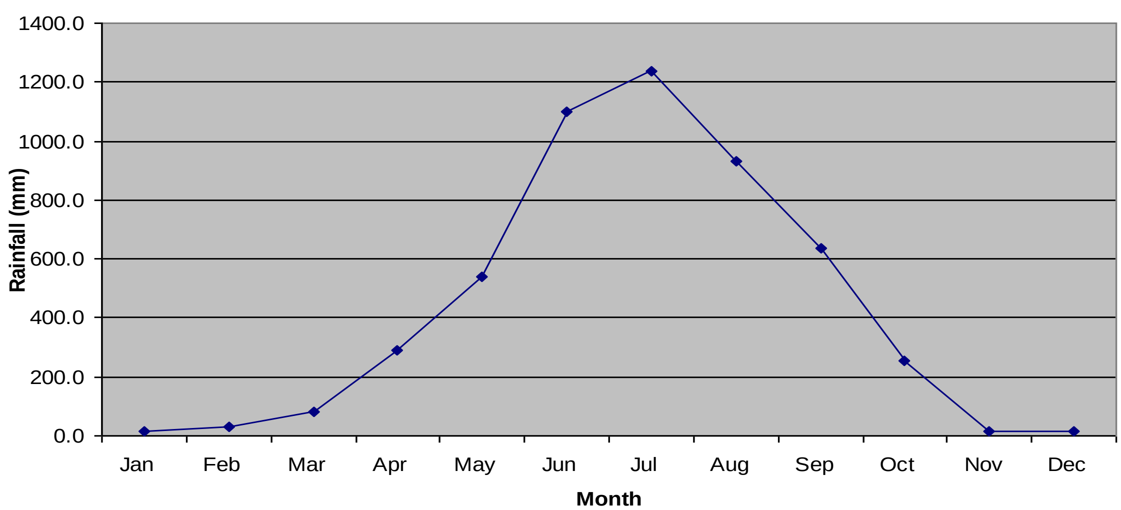

Figure 6. Mean rainfall for each month (Bhur, 1996-2006)

Data source: Meteorology Section, Hydromet Services Division, Department of Energy, Bhutan

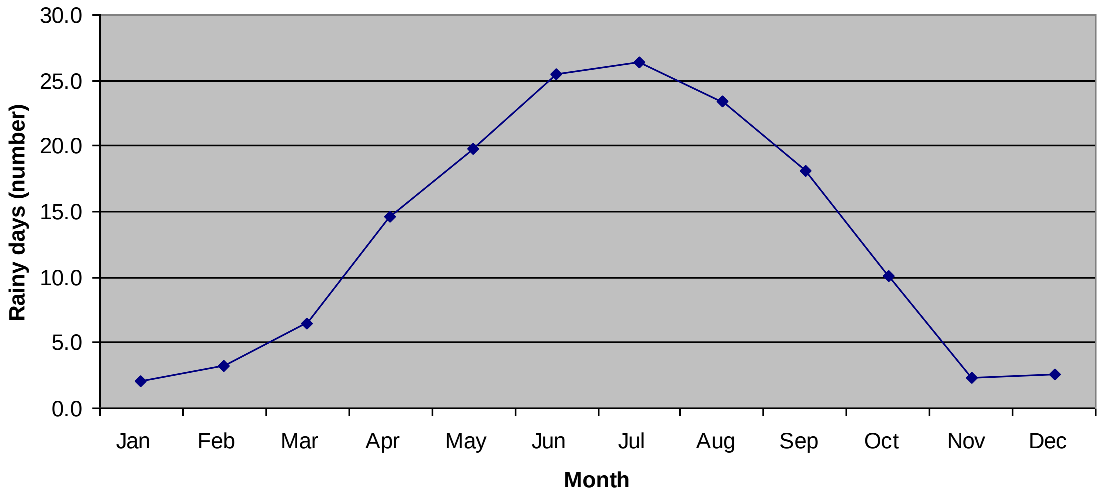

Figure 7. Mean number of rainy days for each month (Bhur, 1996-2006)

Data source: Meteorology Section, Hydromet Services Division, Department of Energy, Bhutan

Table 2. Mean, range and coefficient of variation (CV) for monthly rainfall, 1996-2006.

Month	Rainfall (mm)				Number of Rainy days			
	Mean (mm)	Range (mm) Low	Range (mm) High	CV (%)	Mean (no.)	Range (no.) Low	Range (no.) High	CV (%)
January	14.2	0.0	42.4	84.0	2.1	0	5	72.4
February	31.2	0.0	198.8	186.1	3.3	0	8	79.8
March	79.2	6.6	309.6	105.6	6.5	3	15	54.3
April	289.3	11.0	997.7	90.7	14.6	2	21	34.9
May	540.5	237.0	803.0	37.2	19.8	14	25	16.2
June	1097.9	565.7	1670.1	30.4	25.5	20	30	12.3
July	1235.7	699.3	1972.7	35.5	26.4	20	30	11.9
August	931.8	432.2	1881.8	42.3	23.5	16	30	21.2
September	634.7	169.4	998.0	39.4	18.1	9	25	27.7
October	256.4	16.8	589.8	72.1	10.1	4	18	46.6
Novbember	16.3	0.0	45.8	101.8	2.4	0	9	107.5
December	15.2	0.0	77.2	149.3	2.5	0	7	93.6

Data source: Meteorology Section, Hydromet Services Division, Department of Energy
MTI, Thimphu, Bhutan

The monthly temperature pattern over eleven-year period is given in Figure 8. The mean minimum temperature between from May to November (rice growing season) does not go lower than 18^{o}C, indicating the absence of low temperature stress for the rice crop. The mean maximum temperature does not go beyond 31^{o}C. Thus, heat tolerance is not a required trait for rice in the southern belt.

Rice is grown in undulating terrain, from gentle (<10^{o}) to steep (30^{o}) slope. In the 1993 survey, 59% of the rice fields are in gentle slopes, 24% in gently undulating slopes (10^{o} – 15^{o}) and the rest in undulating to steep slopes (15^{o} – 30^{o}). Some 39% of the farmers described their rice fields as fine clay; 25% as clay loam; 32% as sandy loam and 3% as coarse sandy soil. Soils with high sand content have poor water and nutrient holding capacity. The heavy rainfall particularly during peak moon season causes landslides and floods resulting in land degradation/soil erosion and damaged the distribution channels/canals of the perennial and seasonal irrigation systems.

The lowland rice areas can be entirely rainfed, rainfed with supplementary irrigation and fully irrigated. A given field in a sloping area may have terraces that can access water from nearby spring channels while other terraces are fully dependent on rainfall. In a number of cases, a fully irrigated area becomes a rainfed lowland when the water source channel is damaged by floods in certain years. Thus, the exact area devoted to each is not well documented due to lack of clear cut delineation between irrigated and rainfed lowland areas. However, in the 2003 survey, a farmer’s total rice land on the average was found to be 1.16 ha, of which 1.06 ha were devoted to rainfed lowland and the remainder to fully irrigated lowland. This suggests that around 91% of the rice area in the region is rainfall dependent. It should be noted that farmers are also cultivating an average of 1 ha upland field.

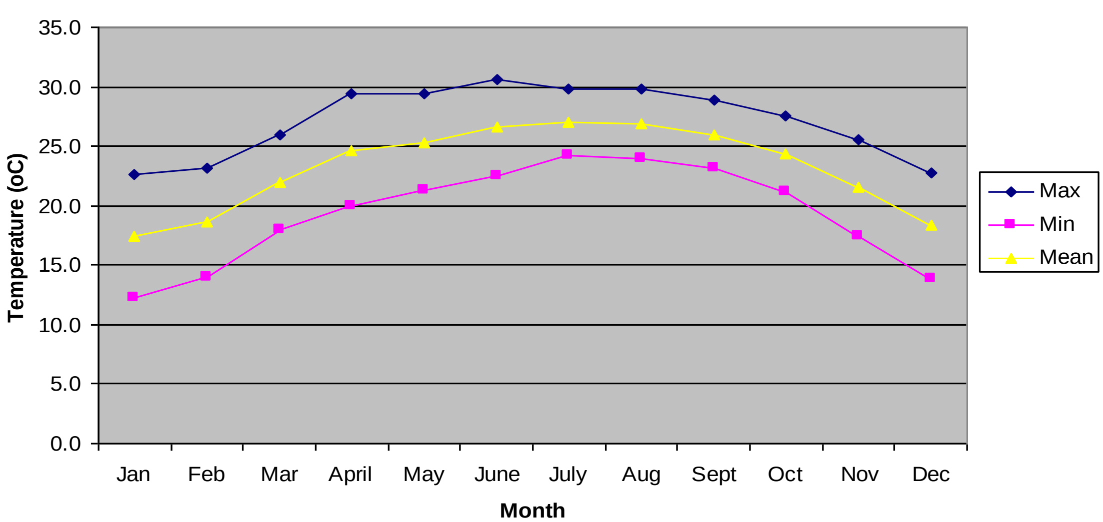

Figure 8. Monthly mean, minimum and maximum temperature (Bhur, 1996-2006)

Data source: Meteorology Section, Hydromet Services Division, Department of Energy, Bhutan

7. Rice-based production practices in Samtse and Sarpang

Seedling establishment starts in the areas surveyed from late May (early monsoon) until late June (late monsoon). Due to the unpredictable rainfall situation, seeding for different varieties is done at different times with the early maturing varieties like BR 153 being sown first. The seed rate on a hectare basis ranges from 48.1 kg to 86.4 kg, with an average of 65.5 kg. The seeding rate is close the recommended rate of 50 kg – 60 kg/ha. Seed broadcast evenly in the field is covered with thin soil by hand or by light planking.

Transplanting is carried out between early June and the first week of August. The wide range of transplanting period is also dictated by the rainfall availability. Delayed transplanting involves seedlings as old as 45 days. Some 54% of households obtain water during transplanting from rainfall activated streams and 23% from reliable perennial rivers/canals. The remainder is dependent solely on rainfall. Random method of transplanting is the norm, with 3-5 seedlings/hill. Replanting missing hills is never practiced. In the 2003 survey, some 3% of the sample households practice direct seeding, it being concentrated in Umling and Ghumauney *geogs*. The unpredictability of rainfall makes direct seeding less popular.

Soil nutrients lost due to crop removal, erosion and leaching are replenished in various ways – tethering, application of cow dung collected, use of chemical fertilizers and combination of organic and chemical fertilizers. Tethering, which is done during fallow period, is the most prevalent practice. Cow dung application is usually carried out few weeks before land preparation. This ensures that farm manure decomposition has taken place already when crop is grown. Only 13% of the rice farmers apply chemical fertilizers according to the 2003 survey report.

Hand weeding is practiced by everybody, usually at two to three weeks after transplanting. Some households may do a second weeding. Application of herbicide along with hand weeding was confined to only 12% of the households surveyed in 2003. Some 18% sprayed fungicides to control fungal diseases and about 29% applied insecticides. Caseworm is generally controlled by draining the water out of the rice field in places where there is assured water source for irrigation.

Harvesting is done by cutting the crop around the base using hand sickle. The harvest is left in the field for 3-7 days to dry and then piled up into a mound (Figure 9). Around 15 days after, threshing is carried out usually by beating dried bundles against stones or wood (95% of respondents). Some beat the bundles with flail (4%) and others trample the bundles using their feet (1%). Seeds are stored in wooden boxes (54% of respondents), gunny bags (36%) or bamboo/cane baskets (10%).

Figure 9. A common practice of keeping the harvest as a mound for 15 days in the field exposes grains to late showers, which eventually reduces milling recovery and palatability.

The predominant cropping patterns are rice-maize and rice-wheat in areas with adequate rainfall. The second crop is immediate planted after harvesting rice around November to take advantage of the residual moisture. When water is not adequate to plant the lowland field with rice, finger millet is grown.

In general, men are responsible for land preparation and women are responsible for transplanting and weeding. Both men and women share the other activities.

8. Critical review of research accomplishments

8.1 Varietal Improvement

8.1.1. Genetic diversity and major attributes of released varieties

Genetic diversity of varieties being cultivated is one of the factors that could stabilize crop production because of its buffering effect on the development of new races of pathogens or insect pest biotypes. Genes controlling resistance are often localized in the nucleus but some may be present in the cytoplasm as in the case of downey mildew resistance in corn. Thus, one approach to study genetic diversity is to look at the nuclear and cytoplasmic background of the released varieties. Because of time limitation, only the ancestral maternal parent of each variety was determined. However, countries of origin of released varieties may reflect nuclear diversity, based on the assumption that different countries utilize their own locally adapted materials.

Since 1988, the National Seed Board has released 17 varieties, of which five, nine and two varieties are for high, mid and low altitude lowland environments, respectively. Eleven of 17 varieties originated from Japan, Nepal, China, Korea, India and IRRI (Table 3). One introduction from Nepal named Chummrong is an IRRI-developed breeding line introduced in Nepal earlier. Six of 17 varieties released were developed by Bhutanese plant breeders, reflecting the RNRRCs capability to generate their own materials using limited resources.

Table 3. Varieties released in Bhutan for different agroecological zones from 1988 to 2006 and their pedigrees.

Release name	Year of release	Designation	Pedigree	Origin
High altitude				
No 11	1989	Takanenishiki	-	Japan
Khangma Maap	1999	Chummrong (IR3941-4-PLP-2B)	CR126-42-5/IR2061-213	IRRI
Yusi Ray Maap	2002	IR62746-B-4-8-1-1	Suweon 359//IR41996-118-2-3 /Thimpu Maap	Bhutan
Yusi Ray Kaap	2002	IR66068-B-B-31-2-1	YR3825-11-3-2-3-1 YR3825-11-3-2-1/Barkat	Bhutan
Jakar Rey Naab	2006	Paro China	-	China
Mid altitude				
IR64	1988	IR64	IR5657-33-2-1/IR2061-465-1-5-5	IRRI
IR20913	1989	IR20913-B-60	IR7149-51-1-3/IR36//Paro White	IRRI
Milyang 54	1989	Gayabyeo	Milyang 21/IR 32//Milyang 23 /Milyang 30	Korea
Barkat	1992	Barkat (K78-13)	Shinei/China 971	India
Bajo Maap 1	1999	CARD21-10-1-1-3-2-1	Local Maap/IR64	Bhutan
Bajo Maap 2	1999	CARD21-14-1-1-3-2-1B	Local Maap/IR64	Bhutan
Bajo Kaap 1	1999	IR61331-2-148-B	IR41996-118-2-1-3/Paro Maap	Bhutan
Bajo Kaap 2	1999	IR61328-1-136-2-1-2-3	IR41996-118-2-1-3?Bja Naab	Bhutan
Wengkhar Rey Kaap 2	2002	Khumal 2 (NR168)	Jarneli/Kn-LD-361-DLK-2-8	Nepal
Wengkhar Rey Kaap 6	2006	Khumal 6 (NR10172-2B-12-4-1-3-2)	IR 13146-45-2-3/IR17492-18-6-1-1-3-3	Nepal
Low altitude				
BR 153	1989	BR153-2B-10-1-3	IR578-172-2-2/BR1-2-B-19	Bangla-desh
BW 293	1990	BW 293-2	IR2070-586/BG400-1	Sri Lanka

The genetic history of all releases except two were traced back until the ancestral female parent (landrace) is obtained using the International Rice Information System. Paro China (introduced in Bhutan without passing through the formal channel) and No 11 (INGER-distributed germplasm believed to originate from Japan) have no pedigree records for genealogical analysis. The ancestral female parents identified for the remaining 15 varieties were Cina (seven releases), Aikoku (two releases), Local Maap (two), Dunghan Sahli (one), Tomoe Nishiki (one), Sikal PL1 (one), and Jameli (one) (Table 4). The first four cytoplasmic sources are land races from Indonesia, Japan, Bhutan and Hungary, respectively. The countries of origin of the others are not known. In general, the varieties released have wide cytoplasmic diversity.

All released varieties have high yield potentials (Table 5). There is a good range for growth duration. Intermediate height is a desirable attribute and BW 293 (dwarf type) is out of the league. Varieties with red pericarp commands a good price. Some releases have this characteristic.

Table 4. Maternal cytoplasm of varieties released for different agroecological zones in Bhutan from 1988 to 2006.

Release name	Year of release	Maternal cytoplasm	
		Identity	Origin
No 11	1989	Unknown	-
Khangma Maap	1999	Dunghan Sahli	Hungary
Yusi Ray Maap	2002	Aikoku	Japan
Yusi Ray Kaap	2002	Sikai PL1	-
Jakar Rey Naab	2006	Paro China	-
IR64	1988	Cina	Indonesia
IR20913	1989	Cina	Indonesia
Milyang 54	1989	Aikoku	Japan
Barkat	1992	Tomoe Nishiki	-
Bajo Maap 1	1999	Local Maap	Bhutan
Bajo Maap 2	1999	Local Maap	Bhutan
Bajo Kaap 1	1999	Cina	Indonesia
Bajo Kaap 2	1999	Cina	Indonesia
Wengkhar Rey Kaap 2	2002	Jarneli	-
Wengkhar Rey Kaap 6	2006	Cina	Indonesia
BR 153	1989	Cina	Indonesia
BW 293	1990	Cina	Indonesia

Table 5. Characteristics of varieties released for different agroecological zones in Bhutan from 1988 to 2006.

Release Name	Yield Potential (t/ha)	Growth Duration (days)	Plant Height (cm)	Grain Color
High altitude				
No 11	5-6	160	90	white
Khangma Maap	4-5	120-130	90-100	red
Yusi Ray Maap	7-8	-	-	red
Yusi Ray Kaap	7-8	-	-	white
Jakar Rey Naab	4-5	-	-	white
Mid altitude				
IR64	6-8	-	80-90	white
IR20913	4-6	130-140	100	white
Milyang 54	6-8	140-145	95	white
Barkat	4-5	155	90-95	white
Bajo Maap 1	6-8	150-155	100-105	red
Bajo Maap 2	6-8	145	100-110	red
Bajo Kaap 1	7-8	145-155	95-105	white
Bajo Kaap 2	7-8	150-155	90-100	white
Wengkhar Rey Kaap 2	4-5	-	-	white
Wengkhar Rey Kaap 6	4-6	-	-	white
Low altitude				
BR 153	4-5	140-150	100-110	white
BW 293	4-5	140-150	75-85	white

8.1.2. Promising varieties in the pipeline: potential contribution on yield increase and genetic diversity

There are a number of outstanding selections undergoing on-farm testing that can be presented to the Varietal Release Committee for review. Table 6 summarizes the yield performance of three selections in researcher-managed and farmer-managed varietal trials based on the 2000-01 to 2005-06 annual reports of RNRRC-Bajo. Guojing 4 and SPR87036-7-1-1-2 have mean yields of 6.76 t/ha and 6.88 t/ha across environments. Their respective yield advantages over that of the variable check variety are 22.3% and 24.5%. The yield of Guojing 4 was higher than that of the check in 14 of 15 trials while the yield of SPR87036-7-1-1-2 is higher than the check in all trials, indicating the test entries' consistent superiority over the check. B2983B-SR853-2-4 has a mean yield of 6.68 t/ha and a yield of 24.0% over the check variety. In general, its performance in individual trials is better than that of the check.

The yield performance of three potential varieties for the low altitude zone is given in Table 7. HB242 has a yield of 4.36 t/ha over nine environments and a yield advantage of 28.4% over the check. Its yield is higher than and at par with the check in eight and one environment, respectively. IR72102-3-115-1-3-2, with a mean yield of 4.53 t/ha over ten testing sites, shows a 41.4% yield advantage over the check. Its yield is higher and lower than the check in nine and one environment, respectively. TOX3098-2-2-1-2-1 has a mean yield of 5.32 t/ha across nine environments and a yield advantage of 53.6%. It outperforms the check in all trials. All test entries outperformed BR153 in environments where it was the check.

All materials have been developed in different national and international research centers. Guojing 4 was developed in China; SPR87036-7-1-1-2 in Thailand, B2983B-SR853-2-4 in Indonesia, and HB242 in Taiwan. IR72102-3-115-1-3-2 is in IRRI and TOX3098-2-2-1-2-1 in Nigeria-based International Institute for Tropical Agriculture. Two of the potential varieties have Cina cytoplasm (Table 8). The others have different maternal cytoplasm and their ancestral female parents are different from those of the previous released varieties. The release of these promising selections will not only increase the varietal options for farmers' use and rice productivity but will also add up to the genetic diversify in farmers' fields.

Table 6. Yields (t/ha) of promising test entries and check varieties for mid altitude environment in researcher- and farmer-managed trials, 2000-06.

Environment[1]	Data Set I			Data Set 2	
	Guojing 4	SPR870 36-7-1-1-2	Check[2]	B2983B -SR853-2-4	Check[2]
2000-01 Observational Nursery	6.90	7.00	4.85	5.90	4.85
2001-02 Initial Evaluation Trial	8.38	7.94	5.35	7.12	5.35
2002-03 Initial Evaluation Trial	-	-	-	7.24	4.59
2002-03 Advanced Evaluation Trial	7.45	7.36	6.74	-	-
2003-04 Advanced Evaluation Trial	8.40	7.87	6.04	7.84	6.04
2004-05 OFAT Nisho, Wangdue	5.94	4.91	4.60	5.53	4.60
2004-05 OFAT Phangyl, Wangdue	3.11	4.33	4.77	4.55	4.77
2004-05 OFAT Tewang, Punakha	6.08	7.39	4.28	6.06	4.28
2004-05 OFAT Kabji, Punakha	5.30	5.50	4.10	6.00	4.10
2005-06 OFAT Ruchika, Wangdue	6.28	7.18	4.77	8.85	4.77
2005-06 OFAT Thangu, Wangdue	9.50	9.50	8.40	8.40	8.40
2005-06 OFAT Maphina, Wangdue	5.23	4.97	4.37	5.73	4.37
2005-06 OFAT Zomi, Punakha	6.79	7.27	5.80	7.27	5.80
2005-06 OFAT Tewang, Punakha	6.53	6.75	6.45	6.07	6.45
2005-06 OFAT Kabji, Punakha	5.98	5.75	4.00	5.17	4.00
2005-06 PVS Thangu, Wangdue	9.50	9.50	8.40	8.40	8.40
Mean	6.76	6.88	5.53	6.68	5.38
% Yield Advantage over the check	22.3	24.5	-	24.0	-

[1]OFAT = On-farm trial, PVS = Participatory varietal selection

[2]Mean is the average of IR64 and Zakha for observational, initial and advanced evaluation trials. It is based on the mean of farmer's local variety at a particular site in OFAT and PVS.

Data Source: Annual Reports of RNRRC-Bajo from 2000-01 to 2005-06.

Table 7. Yields (t/ha) of promising test entries[1] and check varieties for low altitude environment in researcher- and farmer-managed trials[2], 2002-05.

Environment	Data set 1		Data set 2		Data set 3	
	HB242	Check	IR	Check	TOX	Check
Limenthang (PET, 02-03)[3]	6.46	4.85	8.08	4.85	7.47	4.85
Bhur (PET, 02-03)[4]	3.69	2.98	3.05	2.98	3.78	2.98
Bhur (PPET, 02-03)[5]	1.13	0.86	1.30	0.86	-	-
Bhur (IET, 02-03)[6]	3.58	3.04	3.13	3.04	3.89	3.04
Buna (PET, 02-03)[7]	6.45	5.43	9.56	5.43	8.64	5.43
Samtse (PET, 02-037	-	-	1.22	1.43	4.91	1.43
Sarpang (PET, 02-03)[7]	3.56	2.13	3.75	2.13	4.61	2.13
Bhangtar (PET, 02-03)[7]	4.35	3.42	5.30	3.42	4.4	3.42
Limenthang (VxN, 03-04)[8]	5.19	3.06	4.89	3.06	5.30	3.06
Limenthang (VxN, 04-05)[9]	4.84	4.84	5.02	4.84	4.88	4.84
Mean	4.36	3.40	4.53	3.20	5.32	3.46

[1] Complete designations of entries are HB242, IR72102-3-115-1-3-2 and TOX3098-2-2-1-2-1.

[2] PET = production evaluation trial, IET = initial evaluation trial and VxN = variety X nitroger trial.

[3] Data from Annual Report, RNRRC-Wengkar. Check was Tsirang zam.

[4] Data from Annual Report of RNRRC-JWengkar for 2002-03. Check was BR153.

[5] Data from Proceedings of the 10th Regional RNR Review and Planning Workshop, RNRRC-Jakar. Check was Salingpa.

[6] Data from Annual Report of RNRRC-Jakar for 2002-03. Check was BR 153.

[7] Data from Annual Report of RNRRC-Wengkar for 2003-04. Check was Tsirang zam.

[8] Data from Annual Report of RNRRC- for 2003-04. Check was Tsirang zam.

[9] Data from Annual Report of RNRRC- for 2004-05. Check was Tsirang zam.

Table 8. Promising INGER-distributed germplasm for mid and lowaltitude areas of Bhutan and their pedigrees, seed source and ancestral female parents.

Designation	Parentage	Origin of variety	Maternal parent	
			Identity	Origin
Mid altitude				
Guojing 4	Jing Guai2/IR36	China	Jing Guai 2	China
B 2983-B-SR-853-2-4	Sirendah Merah/IR30	Indonesia	Sirendah Merah	Indonesia
SPR87036-7-1-1-2	SPRLR 81074-61-1-1/ IR64// SPRLR 82216-23-1-1	Thailand	Leuang Tawng	Thailand
Low altitude				
TOX3098-2-2-1-2-1	TOX212/UPLRi7	IITA	TOX212	unknown
HB242	Durga/85661-2	China	Dee Geo Woo Gen	Taiwan
IR72102-3-115-1-3-2	IR1561*2/O. Bathii// 4*IR64	IRRI	Cina	Indonesia

Data source: International Rice Information System and INGER database

8.1.3. Adoption of released varieties: national perspective

Varieties grown in Bhutan can be classified into released and Bhutanese traditional varieties. Fifteen of the released varieties are products of hybridization and selection in segregating populations, and thus fall under the category of modern varieties. However, No 11 and Paro have unknown pedigrees and thus could not be classified as traditional or modern varieties. Bhutanese farmers often grow more than one variety in their fields which could be different traditional varieties only, released varieties only and combination of the two varietal groups. In the impact assessment study based on 2002 survey involving 248 households from high, mid and low altitude areas of seven main rice producing dzongkhags, the adoption rates of the fifteen varieties released from 1988 to 2002 was examined. Households growing released varieties only and combination of released and traditional varieties were considered as adopters. Salient findings at the household level analysis are as follows:

- The adoption rate of released varieties across zones was around 60%.
- The highest adoption rate of released varieties was in the high altitude zone (77%) followed by the mid altitude (59%) and low altitude (32%) zones. (In the 2003 survey, the adoption rate found in the low altitude was 44%, which was still lower than that of other altitude zones.)
- Some 56% of the households across zones grew released varieties only and combination of released and traditional varieties.
- The frequencies of households growing released varieties only and combination of released and traditional varieties were 77% in the high altitude zone, 58% in the mid altitude and 32% in the low altitude (56 % in the 2003 survey report).
- The rate of adoption gradually increased from 1989 to 1993, accelerated from 1994 to 1998, and then gradually tapered.

The last one may suggest that Bhutan is reaching the saturation level for adoption of released varieties. If this is the case, then further yield increase associated with varietal adoption can only be attained by releasing more varieties with higher yield potential and farmer-preferred grain qualities or using more inputs such as fertilizers, be organic or inorganic, and better control measures for weeds, diseases and insect pests. It should be noted that reaching the saturation level can also be due to seed availability.

Varietal adoption in terms of area planted was also examined in the 2002 strvey. The area grown with released varieties is about 35%. Partitioning of the data at the altitude level indicated 66%, 38% and 17% adoption rates in high, mid and low altitude zones, respectively. Further partitioning at the variety level revealed that most varieties released/selected under a particular altitude zone were planted not only in their target altitude zone but also in other altitudes (Table 9). This reflects the spill-over effect of research efforts in a given altitude zone in other environments. IR 64 had the widest adaptation having been grown in all altitude zones. In contrast, BR 153 which was selected under low altitude was only grown under that environment, indicating narrow adaptation. Yusi Ray Maap and Wengkhar Ray Kaap 2 were released at the time the survey was conducted but had been included in on-farm trials earlier. They were being cultivated in their selection environments but may find their own niches in other environments over time. Old releases such as Barkat (1992), BW 293 (1990) and Milyang 54 (1989) were not cited by farmers in the survey which may mean that they were no longer cultivated (short varietal life span) or grown only in limited areas (site-specific adaptation). On the contrary, IR 64, BR 153 and IR20913 have a long varietal life span, having been grown by farmers since the late 1980s until now. Yusi Ray Kaap which was released in 2002 was also not mentioned by farmers in the 2002 survey. It may take sometime before one can make a judgment on its usefulness and longevity.

8.1.4. Adoption of released varieties: the southern belt experience

Thirty three local varieties were grown by farmers in Samtse and Sarpang (Table 10) based on the 2003 survey report. In the geogs visited that were not included in the survey, there were nine additional varietal names given: Doley Katey, Jeerasaree, Bhumpa Dhan, Balimusli, Musoli, Kalture, Katike, Bangko and Motai. Thus the total number of putative traditional varieties in the two districts is at least 42.

Table 9. Percent area under each variety released from 1988 to 2002 in places growing improved varieties situated in different altitudes

Released varieties	Selection/target environment of released varieties	Year released	Altitude of surveyed area			
			High	Mid	Low	Across altitudes
Khangma Maap	High altitude	1999	77.3	14.2	0.0	61.7
No 11	High altitude	1999	17.2	53.6	0.0	15.8
Yusi Rey Maap	High altitude	2002	25.2	0.0	0.0	7.1
IR64	Mid atitude	1988	24.4	93.6	100.0	92.5
IR20913	Mid atitude	1989	75.6	6.4	0.0	7.5
Bajo kaap 1 and 2	Mid atitude	1999	34.0	44.4	0.0	41.5
Bajo Maap 1 and 2	Mid atitude	1999	40.9	55.6	0.0	51.4
Wengkhar Ray Kaap 2	Mid atitude	2002	0.0	19.7	0.0	0.8
BR 153	Low altitude	1989	0.0	0.0	69.4	11.6
Unidentified varieties	Unknown	-	5.5	12.5	30.6	10.0

Data source: 2002 survey report in economic impact assessment paper, p 47 (modified).

Table 10. Cultivated landraces and their charcteristics based on farmers' perceptions in Samtse and Sarpang

Varieties	Yield stability	Taste/scent	Pericarp color	Maturity days	DP	Thresh-ability
Achamay	-	Poor	White	145-160	s	Easy
Attey	Stable	Good	White	90-120	-	Very easy
Aumusli/ Musli	-	-	White	100-120	s	Easy
Babu Jasuwa	Stable	-	White	-	-	Easy
Bakhri-kotay	Unstable	Good	White	-	-	-
Balingpa	Unstable	Good	Red		s	-
Baudhan	Unstable	Good	White	-	-	Easy
Bayarni Dhan	-	Good	White	145-160	-	Hard
Champa-suri	Stable	Good	White	-	-	Easy
Chettri Mansara	Stable	Medium	White	145-160	-	Very easy
Chotakati	-	Good	White	-	-	Easy
Choti Masino	Unstable	Good	White	90-120	s	Easy
Dutkalam	-	Good	White	-	-	-
Gauria	-	Good	White	-	s	-
Jadu	-	Poor	White	145-160	-	Easy
Japaki	Unstable	-	White	-	s	-
Jasuwa	Stable	-	White	-	-	Easy
Juwadhan	Unstable	Medium	White	-	-	-
Kalo Noonia	Stable	Good & scented	White	145-160	s	Hard
Katiksali	Unstable	Medium	White	150-160	R	-
Khatkiri	Stable	Poor	White	100-130	-	Easy
Krishna Bhog	Unstable	Good & scented	White	-	s	Hard
Malinginy	-	-	White	-	-	Easy
Malsira	Stable	Good	White + red	100-120	-	Easy
Mama	Stable	Good	White	110-120	-	Very easy
Mauli	Unstable	Good	White	145-160	s	Very easy
Morangay	Unstable	Medium	White	-	-	Easy
Pakha Dhan	-	Good	White	-	-	-
Ranigajal	-	Good & scented	White	145-160	s	-
Rato Mansara	Stable	Poor	White	-	-	Hard
Timburay	Stable	Medium	White	150-170	-	Easy
Tsirangzam	-	-	White	-	-	Easy
Wangdakam	-	-	White	-	-	Easy

Legend: DP = Disease and pest resistance where s is suceptoible and R is resistant
Data source: 2003 Survey Report

The reasons provided by farmers for cultivating the traditional varieties being maintained are as follows:

- Good grain characteristics such as high palatability, aroma and grain size. Small and bold grains, similar to the premium rice of Sri Lanka called *Samba* type, are preferred because of very high milling recovery.
- Ease of threshing. This is a labor-saving trait.
- Stability of performance. A variety that could consistently produce grains, even if the yield is low, regardless of rainfall regimes provides a feeling of food security.
- Growth duration. Cultivated local varieties could fall into two maturity groups – early maturing (90-130 days) and late (145-170) maturing. This variation in growth duration could distribute the labor requirement and food supply over time.

In the 2003 survey, the 7 modern varieties mentioned to be grown are BR1 153 (Figure 10), IR 64, Bajo Kaap 1, Bajo Kaap 2, Bikashi, IR 8 and Pusa 33. In the 2002 survey, BR 153 accounted for 70% of the households growing modern varieties, followed by IR 8 with 15%. The average yield of modern varieties was 380 kg/ha more than that of the traditional varieties, or a yield advantage of 26% in the 2002 survey (Table 11), which could be attributed mainly to the high yield of BR 153 and not of other modern varieties. The mean yield of BR 153 was 3,019 kg/ha for eight farmers interviewed recently in geogs not included in the 2003 survey and that of their traditional varieties was 2,099 kg/ha. The yield advantage of BR 153 is close to 1 t/ha.

Approximately 56% of the households grow traditional varieties only, 28% grow both traditional and modern varieties, and 16 grow modern varieties in Sarpang and Samtse dzongkhags. For those growing both traditional and modern varieties, the area for the latter is smaller than that of the former.

The most widely grown modern variety is BR 153 which has been selected for low altitude environments. Its higher yield potential and stability, shorter growth duration and better resistance to pest diseases than the local varieties are the major attributes for its adoption. Its negative traits are poor taste, not so easy to thresh, low milling recovery with many broken grains, and short straw. Straw yield is very important since it is used as animal feed and sometimes as roof for houses. A number of farmers interviewed mentioned that BR 153 straw is not palatable for cows and rots easily. A family with many members ignores these negative traits because of its yield potential and ability to escape drought because of its short growth duration. It is often mentioned that the poor quality of modern varieties is still better than that of rice imported from India that they buy during lean months.

IR 64, Bajo Kaap 1 and Bajo Kaap 2 are not adapted in the unfavorable areas of the southern belt since they have been selected for mid altitude zones.

However, few farmers grow them because of their resistance to insect pests and diseases. Although known to have poor qualities and susceptibility to stresses, IR 8 is still grown to a limited extent for its high yield potential under high input favorable environment.

Figure 10. A good stand of BR 153 is observed in a farmer's field at Chhuzargang.

Table 11. Average yield (t/ha) of traditional and modern varieties in Sarpang and Samtse.

District	Traditional varieties	Modern varieties[1]	Difference
2003 Survey (n = 33)			
Sarpang	1326	1704	379
Samtse	1650	2033	382
Mean	1489	1869	380
2006 Survey (n = 8)			
Samtse and Sarpang	2099	3019	920

[1] In 2003 survey, data were based on a number of modern varieties; in 2006, modern variety data was from BR 153 only.

8.15. Cost-effective varietal improvement strategies

The development and release of a new variety is a long process. It takes a minimum of seven years to produce a relatively stable line (F6 generation) and some years of on-station and on-farm testing before that line is released, given one growing season per year as in Bhutan. Cognizant of the above, the rice varietal improvement research component has made the International Network for Genetic Evaluation of Rice (INGER), the major germplasm exchange program under IRRI, an integral component of its testing program. From 1979 to present, INGER has provided Bhutan more than 14,000 seed packets of 10,167 varieties and breeding lines in 34 yield, observational and screening nurseries (Table 12). Introductions came from various national and international breeding centers Seven released varieties (IR64, IR20913, Barkat, No 11, Milyang 54, BR153, BW293) were extracted from INGER nurseries. The six potential varieties for mid and low altitude zones are also INGER-distributed germplasm.

Not all desirable attributes needed by rice farmers are present in foreign introductions. Thus, some research efforts have been devoted to the development of new materials with varieties adapted to the local growing conditions as parents. Because of limited trained manpower and resources for hybridization work, IRRI was requested to generate a number of segregating populations for Bhutan, using the parents suggested by the local staff. However, selection in segregating generations was done entirely in Bhutan. More than 140 crosses have been produced and thousands of breeding lines have been evaluated over the years. Six breeding have been approved by the National Seed Board for commercial use, namely: Yusi Ray Maap, Yusi Ray Kaap, Bajo Kaap 1, Bajo Kaap 2, Bajo Maap 1 and Bajo Maap 2. For the first four varieties, generation of F2 populations was done at IRRI but selection in succeeding generations was made in Bhutan. All steps in the development of the last two varieties were conducted in the country. A number of recent breeding lines developed by Bhutanese look very promising in on-station trials.

Direct utilization of varieties developed elsewhere is a cost-effective strategy since it takes at least 6 years to develop a new material from the time a cross is made, given one crop cycle per year as in Bhutan

8.1.6. Growing rice beyond 2500 masl

Rice cultivation is not a traditional farming system in Bumthang. It has been the belief that Bumthang's agricultural area which is located in altitude ranging from 2500 m to 2800 is too cold to support rice growth and development. Bumthang's altitude is beyond the range being used in selecting varieties for high altitude zone and will require higher degree of cold tolerance. The testing of selected traditional varieties, released varieties and foreign introductions commenced in 1997. On-farm research efforts have resulted in the identification of Paro China and Khangma Maap as suitable varieties. Farmers' acceptance of

Paro China has led to its formal release in 2006. Today, about 18 ac are devoted to rice cultivation and the area is expected to increase with the utilization of uncultivated marshy areas and portions of large flat lands. There are abundant water resources in Bumthang. The average yield in Bumthang from 2004 to 2005 was 3.97 t/ha (Table 1) which is about one ton higher than the national average during the said period. Expanding the rice area in Bumthang is beneficial to the people who have to purchase rice all the time.

Table 12. INGER nurseries requested by RNRRC-Bajo and number of entries per nursery, 1979-2007.

Nursery*	79	80	83	84	85	86	87	88	89	90	91	92	93	94
IRON-E	-	-	-	-	-	31	26	14	21	-	-	-	-	-
IRON-M	-	-	-	395	-	76	61	84	85	-	-	-	-	-
IRON-M	-	-	-	-	-	74	90	104	77	-	-	-	-	-
IRYN-VE	-	-	29	29	-	23	24	24	29	-	-	-	-	-
IRYN-E	-	-	28	29	-	24	24	23	-	-	-	-	-	-
IRYN-M	-	-	-	-	27	22	24	24	-	-	-	-	-	-
IIRON	-	-	-	-	-	-	-	-	-	312	168	152	122	195
IIRON-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IRFAON	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IRBON	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IRHON	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IRYN-VE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IRYN-E	-	-	-	-	-	-	-	-	-	-	-	28	-	-
IRYN-M	-	-	-	-	-	-	-	-	-	-	-	26	-	-
IRLON	-	-	-	-	-	-	-	-	-	147	172	66	83	48
IRLYN-M	-	-	-	-	-	-	-	-	-	-	-	20	-	-
IRRSWON-E	-	-	-	-	-	-	14	16	-	-	-	-	-	-
IRRSWON-M	-	-	-	-	-	126	75	111	-	-	-	-	-	-
IRRSWYN-E	-	-	-	-	-	17	-	-	-	-	-	-	-	-
IRRSWYN-M	-	-	-	-	-	16	-	21	-	-	-	-	-	-
IURON	-	-	-	-	-	-	-	-	-	189	175	122	-	77
IURON-E	-	-	-	-	112	102	-	-	-	-	-	-	-	-
IURON-M	-	-	-	-	180	-	-	-	-	-	-	-	-	-
AERON	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acid upland	-	-	-	-	-	-	-	63	-	-	-	-	-	-
Acid lowland	-	-	-	-	-	-	-	-	26	-	-	-	-	-
IRSATON	73	-	-	-	-	-	-	-	-	-	-	-	-	-
IRTON	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IRCTN	-	245	101	175	184	88	63	73	58	79	106	82	-	-
IRDSN	-	-	-	-	-	-	-	-	46	-	-	-	-	-
IRDTN	-	-	-	-	-	-	-	-	-	61	80	-	-	-
IRBN	-	-	-	-	373	-	-	-	-	-	382	328	-	-
IRBPHN	-	-	-	-	-	-	-	67	-	-	-	-	-	-
IRSBN	-	-	-	-	-	-	-	-	34	-	53	-	-	-
Total	73	245	158	628	876	599	401	624	376	788	1136	824	205	320

Table 12. (continued)

Nursery*	95	96	97	99	99	00	01	02	03	04	05	06	07	Total
IRON-VE	-	-	-	-	-	-	-	-	-	-	-	-	-	92
IRON-E	-	-	-	-	-	-	-	-	-	-	-	-	-	701
IRON-M	-	-	-	-	-	-	-	-	-	-	-	-	-	345
IRYN-VE	-	-	-	-	-	-	-	-	-	-	-	-	-	158
IRYN-E	-	-	-	-	-	-	-	-	-	-	-	-	-	128
IRYN-M	-	-	-	-	-	-	-	-	-	-	-	-	-	97
IIRON	167	-	78	78	98	-	88	130	133	150	78	57	39	2045
IIRON-2	-	-	-	-	-	-	-	-	-	-	-	-	27	27
IRFAON	-	-	-	59	-	-	-	-	-	-	-	-	-	59
IRBON	78	78	-	-	-	-	-	-	-	-	-	-	-	156
IRHON	-	-	-	79	-	-	-	-	-	-	70	-	-	149
IRYN-VE	-	-	-	-	-	-	-	-	-	-	-	-	-	0
IRYN-E	-	-	-	-	-	-	-	-	-	-	-	-	-	28
IRYN-M	-	-	-	-	-	-	-	-	-	-	-	-	-	26
IRLON	-	-	-	78	54	74	-	82	82	58	30	83	97	1154
IRLYN-M	-	-	-	-	-	-	-	-	-	-	-	-	-	20
IRRSWON-E	-	-	-	-	-	-	-	-	-	-	-	-	-	30
IRRSWON-M	-	-	-	-	-	-	-	-	-	-	-	-	-	312
IRRSWYN-E	-	-	-	-	-	-	-	-	-	-	-	-	-	17
IRRSWYN-M	-	-	-	-	-	-	-	-	-	-	-	-	-	37
IURON	55	-	-	79	59	54	-	-	-	-	-	121	-	931
IURON-E	-	-	-	-	-	-	-	-	-	-	-	-	-	214
IURON-M	-	-	-	-	-	-	-	-	-	-	-	-	-	180
AERON	-	-	-	-	-	-	-	-	-	-	82	-	-	82
Acid upland	-	-	-	-	-	-	-	-	-	-	-	-	-	63
Acid lowland	-	-	-	-	-	-	-	-	-	-	-	-	-	26
IRSATON	-	-	-	-	-	-	-	-	-	-	-	-	-	73
IRTON	-	-	-	-	-	88	-	-	-	-	-	-	-	88
IRCTN	-	-	-	-	67	-	-	-	-	-	-	-	-	1321
IRDSN	-	-	-	-	-	-	-	-	-	-	-	-	-	46
IRDTN	-	-	-	-	-	-	-	-	-	-	-	-	-	141
IRBN	-	-	-	184	-	-	-	-	-	-	-	-	-	1267
IRBPHN	-	-	-	-	-	-	-	-	-	-	-	-	-	67
IRSBN	-	-	-	-	-	-	-	-	-	-	-	-	-	87
Total	300	78	78	557	278	216	88	212	215	208	260	261	163	10167

Table 12 (continued)

Acronym*	Meaning
IRON-VE	International rice observational nursery - very early
IRON-E	International rice observational nursery -early
IRON-M	International rice observational nursery - medium
IRYN-VE	International rice yield nursery - very early
IRYN-E	International rice yield nursery - early
IRYN-M	International rice yield nursery - medium
IIRON	International irrigated lowland rice observational nursery
IIRON-2	International irrigated lowland rice observational nursery - module 2
IRFAON	International fine grain aromatic rice observational nursery
IRBON	International boro rice observational nursery
IRHON	International hybrid rice observational nursery
IRYN-VE	International irrigated lowland rice yield nursery-early
IRYN-E	International irrigated lowland rice yield nursery-medium
IRYN-M	International rainfed lowland yield nursery- medium
IRLON	International rainfed lowland rice observational nursery
IRLYN-M	International rainfed lowland yield nursery - medium
IRRSWON-E	International rainfed shallow water observational nursery - early
IRRSWON-M	International rainfed shallow water observational nursery - medium
IRRSWYN-E	International rainfed shallow water yield nursery - early
IRRSWYN-M	International rainfed shallow water yield nursery - medium
IURON	International upland rice observational nursery
IURON-E	International upland rice observational nursery - early
IURON-M	International upland rice observational nursery - medium
AERON	International aerobic rice observational nursery
Acid upland	-
Acid lowland	-
IRSATON	International soil
IRTON	International temperate rice observational nursery
IRCTN	International cold tolerance observational nursery
IRDSN	International rice drought screening nursery
IRDTN	International rice drought nursery
IRBN	International rice blast nursery
IRBPHN	International rice brown planthopper nursery
IRSBN	International stemborer nursery

Data source: International Network for Genetic Evaluation of Rice Information System

8.1.7 Conserving the building blocks of modern varieties

Bhutan has a wealth of traditional varieties that are adapted to its diverse rice-growing environments. For hundred of years, natural and farmers' selection pressures have contributed significantly to the evolution of the current land races. The intrusion of modern varieties and urbanization are the commonly given reasons for genetic erosion. The 2003 survey in Samtse and Sarpang, provided a different scenario on genetic erosion. Farmers reported to have cultivated 17 more landraces that are either lost or are on threat of being lost forever (Table 13). Low yield generally characterized traditional varieties. In the 2003 survey, 40% of the households cited it as the major reason why a variety was no longer grown. In general, traditional varieties grown are prone to lodging and this could contribute to yield reduction. Around 38% of the respondents considered late maturity as a negative attribute. Late maturing varieties have longer time exposed to abiotic and biotic stresses in the field than earlier maturing varieties. In general, most cultivated land races are susceptible to insect pests and diseases. More than half of households cited late maturity also considered non-uniformity as a negative trait. A landrace is composed of several genotypes that could differ in certain traits such as growth duration, height and grain type, to mention a few. Thus, genetic erosion can also take place because certain traditional varieties no longer meet changing needs of the farmers.

The success of a breeding program is dependent to a large extent on the availability of a genetically diverse germplasm from which parental materials are selected. About 500 local rice varieties have been collected from the major rice growing areas of the country. They are being conserved at the Royal Bhutan Crop Genebank which was established in 2005 under the National Biodiversity Center (NBC). RNRRCs are actively involved in *in situ* conservation of traditional varieties. On-farm conservation is being implemented through the Biodiversity Use and Conservation in Asia Program (BUCAP) under the leadership of the NBC. Employing both ex situ and in situ conservation is a significant accomplishment of the of the rice improvement team.

Duplicate samples of 356 out of 500 accessions have been deposited in the IRRI Genebank for safe keeping. Duplicate samples of the other accessions should be stored at the IRRI Genebank to ensure that that they will remain available in case the samples at NBC encounter some problems. All rice germplasm at IRRI Genebank are under the auspices of the Food and Agriculture Organization and IRRI just serves as a caretaker.

8.2. Crop management and post harvest technologies

Research efforts along the development of improved agronomic, nutrient management, pest management, post harvest and cropping systems practices have focused on how to enhance the expression of a variety's yield potential, taking into consideration farmers' available resources and capacity to purchase inputs. Research outputs are consolidated into packages of recommendations and options for increasing crop productivity. Some highlights are:

- Technology package/options are available for released varieties for different agroecological zones.
- Technology package/options are available for double rice cropping, direct seeding and rice ratooning.
- Dzhongkag-specific fertilizer recommendations for both traditional and released varieties have been developed.
- Several options on crop rotation practices that would enhance rice productivity and/or farmers' income have been developed.

Attention is also given to specific problems that farmers deemed important, emerging problems that could reduce rice productivity and new strategies that could improve rice production or research methodology. Major outputs along the above are the following:

- Management practices that could help in controlling blast problem have been developed.
- Effect of various planting methods and time of planting on yield have been conducted.
- Cultural management practices and herbicides that control a new weed problem, locally called *sochum* (*Potamogeton distinctus*), have been identified.

Table 13. Landraces listed by farmers as lost in 2003 survey in Samtse and Sarpang

Varieties	Geog previously found	Place found now
Anadey	Ghumauney	Not found anymore
Kumtedhan	Sibsoo	Not found anymore
Panisali	Changmari	Not found anymore
Ram Bhog	Umling, Ghumauney	-
Ram Bhota	Ghumauney, Changmari	Not found anymore
Awanpakhay	Changmari	Not found anymore
Katusay	Changmari	Not found anymore
Bhukul	Ghumauney	Not found anymore
Bagay Tulasi	Sibsoo	Other geogs
Tegmaru	Jigmecholing	Not found anymore
Ram Tulasi/ Tulasi	Sibsoo	Nearby Geogs
Choti Noonia	Sibsoo	Not found anymore
Bhachi	Ghumauney, Sibsoo	Other geogs
Lajum	Gelephu	Not found anymore
Muwadhan	Changmari	Not found anymore
Bhurku	Ghumauney	Not found anymore
Dewpaney	Sibsoo	Not found anymore

Data source: 2003 Survey Report

- Polytunnel method of raising seedlings during cold months has been proven effective and can now be tried in the first crop of a double cropping system and in rice production at very high elevation (Bumthang).
- The pre-rice green manuring crop, Dhaincha (*Sesbania aculeate*) has been re-introduced in the low altitude rice growing areas.
- Chinese milk vetch (astragalus sinicus) has been identified as suitable green manure crop for elevation above 1,300 m for winter crop.
- Grain moth (*Sitotroga cerealella*) and grain weevil (*Sitophilus oryzae*) have been confirmed as the major seed storage problems of rice farmers.
- The farmers' practice of sealing basket with cow dung or mud has been confirmed effective for seed storage.
- Sampling procedures and methods for measuring field crops yields have been developed for taking crop cuts

Extension agents are always updated on recent technologies that can be introduced to rice farmers through meetings and leaflets.

The three discipline-based component technologies developed for the southern belt below involved commercial agricultural inputs are as follows:

- nutrient management using synthetic fertilizers in the absence of or in combination with farm yard manure;
- weed management using herbicide in conjunction with hand weeding;
- integrated disease and insect pest management using pesticides when cultural and biological control measures are not adequate.

The use of chemical fertilizers is limited to some 13% of the households, herbicide to 12% and insecticide to 29%. The constraints to adoption given by the farmers are the following:

- commercial inputs are not available in some areas;
- commercial inputs are available but not on time needed;
- cost of inputs is high relative to some households' purchasing power.

The first two are the most important reasons considered by farmers. The Druk Seed Corporation is a semi-government corporation involved not only in the seed business but also in the importation, distribution and sale of commercial agricultural inputs. It has private individuals acting as commission agents responsible for agricultural input distribution and sale in various geogs. Extension agents provide the input demand of farmers to the corporation. Thus, the input availability constraint is due to certain linkage problem involving the Druk Seed Corporation, commission agents, extension agents and farmers.

The high cost of agricultural inputs is one reason for using only moderate amounts instead of the recommended fertilizer rate or for not using any commercial fertilizer. This is expected in the subsistence farming system of the rainfed environment where farmers have limited funds. The other reason is the production risks associated with rainfed environment. Farmers recognize that the high cost of fertilizers may not be recovered due to possible drought or floods that could wash away soil nutrients.

8.3. Socio-economics and policy

The most notable achievement of the socio-economics and policy research component is the economic impact assessment of the national rice research program implemented during the last two decades. The study was jointly conducted by the socio-economics staff of the four RNRRCs in collaboration with IRRI in 2002. It was based mainly on a farm survey conducted in seven dzongkhags that account for 62% and 64% of the total rice area and production, respectively, of Bhutan. Some of the major impacts of rice research are as follows:

- Improved rice technologies increased rice production by 58% from 1989 to 1997 despite a 9% reduction in rice area. This led to the stabilization of annual rice imports to 33,000 t in recent years despite the population growth.
- National rice output increased by 5,000 to 10,000 t per year, the farm-gate values of which are Nu 60 million to Nu 121 million per year, respectively.
- Adoption of Improved technologies increased the farmers' net income of more than Nu 9,000/ha. This means a gain in net returns nationally of Nu 58 million to Nu 118 million.
- Around 60% of the households are cultivating released varieties in some 35% of the rice area.
- Around 68% of the households have achieved self-sufficiency in rice.
- Adopters of improved technologies have more than 110% more cash income than non-adopters. This could be partly due to improved rice yields that enabled farmers to diversity into high value cash crops.
- The rice research program has been a major contributor in building the research capacity of the country.

9. Production constraints and research opportunities In Samtse and Sarpang

The uncertainty of the onset, amount, duration and distribution of rainfall that beset the rainfed rice environment is the overriding factor that limits rice productivity in the southern belt. Severe drought is often encountered around October when late maturing varieties are in the reproductive stage. This was observed during the consultant's field visits in Samtse and Sarpang (Figure 11 and 12). The national rice research program has generated improved technologies that will enhance yield productivity in the low altitude zone. The adoption and constraints to adoption of improved technologies discussed in the preceding section indicate improved technologies' strengths and weaknesses, and thus, useful in the overall assessment of the production constraints and the challenges ahead. Discussed below are the production constraints specific to the rainfed lowland s in the south and research opportunities ahead.

Figure 11. Rice crop severely affected by drought at reproductive stage in Sipsoo (above) and Bawangoen, Ugyentse (below) will produce empty or few filled grains.

Figure 12. A large number of fields in Sipsoo (above) and Thendu (below) are suffering from drought at reproductive stage because of early recession of the monsoon.

9.1. Varietal constraints

Of the two released varieties for the rainfed lowland environment, only BR 153 has been adopted by a reasonable number of households. Farmers have tried growing varieties released for other environments with no comparable yield advantage with BR 153 with limited success. The big challenge is to provide farmers with a set of genetically diverse varieties that are adapted to rainfed environments and with desirable attributes missing in BR 153 like high level of tolerance to drought.

The immediately solution is to expand the on-farm testing program of three promising low altitude-adapted introductions discussed under Research Accomplishments (see topic 8.1.2). The medium term solution is to broaden the search for new introductions by including the upland rice nurseries among the nursery types being requested from INGER. During the visit in a site at Sipsoo where there is severe water stress, the only good looking crop was that of an introduced upland variety. In other sites visited, farmers were also asking about upland materials. Upland varieties are adapted under non-flooded condition but they can also grow well under lowland condition. The long-term solution is to develop genetically diverse modern varieties with good and stable yield even when there is under drought, short growth duration, intermediate height, non-lodging behavior, resistance to major diseases, farmer-preferred grain qualities (small bold grains, intermediate amylose content, soft cooked rice and good milling recovery) and good panicle threshing ability. This will entail the utilization of local and foreign germplasm as parents in crosses.

9.2. Biotic constraints

Weeds, diseases and insects pests impinge on the growth and development of plants. Farmers reported in the surveyed geogs that yield could be reduced by as high as 50% each by weeds and disease infestation and by 24% by insect pests (Table 14).

There are two unidentified disease problems that have been observed by farmers in recent years. One disease has been reported by 47% of surveyed farmers and manifests whitish panicles that fail to form grains. The other disease is reported by 20% of the respondents and is characterized by yellowing and then drying of whole plants in patches (Figure 13). It can be observed as early as the early vegetative stage. There is an immediate need for crop protection specialists and agronomists to determine if the disease is due to biotic stress, nutritional problem or drought.

The other reported diseases are base-rot at vegetative stage, leaf spots at tillering stage (Figure 14) and node blast at reproductive stage. A traditional practice by some farmers during disease outbreak is draining water out from the field. Pathologists should asses if practice is effective and thus could be added to the pool of recommended management options that are not chemical-based.

In general, there is no known true rice varietal resistance to most insect pests. Varietal differential response to insect pests is more of preference than true resistance, although for stemborer, genetic variability for certain level of tolerance is available. Integrated pest management option is the main recourse for pest control. This would necessitate the use of insecticides in some cases. Constraints on the utilization of commercial insecticides along with other agricultural inputs such as fungicides and chemical fertilizers are their availability and costs (see last two paragraphs of topic 8.2). There is a need to ferret out and identify solution to the problem in the agricultural input supply and demand involving the Druk Seed Corporation, commission agents, extension agents and farmers.

Table 14. Percent of respondents (n = 76) expressing biotic pest problems in the field and during seed storage and associated percent yield reduction

Biotic Constraint	% Respondents		% Yield reduction	
Weeds	90		50	
Diseases	75		50	
Unidentified disease 1[1]		47	-	
Unidentified disease 2[2]		20	-	
Base-rot		20	-	
Leaf-spots		7		
Node blast		7	-	
Insect pests in the field	79		24	
Stem borer		37		28
Case worm		35		25
Others		28	-	
Caterpillar/leaf miner				19
Cutworms				15
Hopers/aphids/locust/bugs				16
Vertebrate pests	90		47	
Elephants		42	-	
Monkeys		26	-	
Others		32	-	
Storage pests			13	
Grain moths		55	-	
Weevil		31	-	
Rats		12	-	
Others		2	-	

[1] Unidentified disease symptoms are whitish and empty panicles.

[2] Unidentified disease 2 symptoms are yellowing and drying of whole plants in patches

Data source: 2003 Survey Report

Figure 13. A crop with unidentified disease characterized by yellowing (above) followed by drying of whole plants (below) in patches is observed in a number of fields in Sarpang.


Figure 14. Leaf spot is one of the diseases of rice in Bhutan.

9.3. Soil fertility constraints

The undulating terrain, loose soil structure, deposition of unwanted debris during landslides and floods, and soil erosion are contributing factors to the impoverished nutrient status of rice fields. In addition to the constraints associated with chemical fertilizer usage there is a need to understand why green manuring does not have a place in the community's rice-based farming system.

9.4. Irrigation constraints

There are rainfed lowland areas that may obtain supplementary irrigation from perennial canals/springs/streams and rainfall activated sources. These water channels are being tapped by farmers at vegetative stage, starting at transplanting time to avoid water stress brought about by extended delay of rainfall. The major problem is the erratic supply of water in the existing discharge systems in terms of volume, discharge rate and continuity of supply. Some of the water channels are very old and need reinforcement while others are damaged by floods/landslides and need repair. It is a challenge for the government to provide engineering services to improve the existing water discharge systems.

9.5. Vertebrate pest problems

The natural habitats of elephants, monkey, wild boar and rodents are just a short distance away from farm lands. These vertebrates often roam around rice fields and cause crop damage. The vertebrate pests are responsible for 47% reduction in crop yield (Table 14). Elephants come in herd and can damage 80% to 100% of a standing crop, leaving nothing to harvest. Around 38% of the labor employed in rice production in the southern belt is focused on crop guarding. Guarding the crop is the only control measure that can be done for wild animals and for a herd of elephants, this is often ineffective. Killing elephants and other wild life is against the Buddhist culture of the Bhutanese and the Biodiversity Act of Bhutan. It is therefore a big challenge to the government to find ways to protect both its wild life that destroys agricultural crops and the livelihood of the people dependent on rice production.

9.6. Post harvest constraints

Sun drying is the only system available to reduce the moisture content of the seed to about 14% after harvesting. Extended late showers may take place after harvest and grain quality and milling recovery could be severely affected.

Seed storage pests are reported to reduce the total produce to about 13%. Grain moths and weevil are the major concerns of the farmers (Table 14). Studies on how to control storage insect pests are therefore in order. They could include seed cleaning treatments, air tight containers made of recyclable materials in the locality, and commonly found botanical pesticides such as neem, sindwar leaves and ash.

Proper drying of seeds has important effects on sensory quality of the grain, pest storage pests and seed viability. It is a challenge to the National Post Harvest Center to developed economically efficient small driers that could be managed by a farming community in response to the unpredictable late rainfall.

One factor that may have been contributing to low milling recovery is the old rice mills in villages. There is a need for government to assess the rice mills if they are contributing to the yield loss due to low total and head rice recoveries. Rice mills with rubber rollers to remove the husks are known to produce less broken grains.

9.7. Labor constraints

Non-mechanized lowland rice cultivation is an intensive farming system. Some 387.8 man-days/ha and 49.4 pair of bullocks-day/ha are needed to complete different operations (Table 15). The family labor is not enough to meet the labor requirement. Farm workers are hired at the rate of Nu40 to Nu100/day and/or exchange labor is practiced within the farming community. The cost of hiring a pair of bullocks is Nu130 to Nu180/day.

Delayed monsoon aggravates the labor constraint. Everybody is in a hurry to transplant very old seedlings in the field, thus, greater competition for labor takes place. As a consequence, not all rainfed lowland fields are cultivated. This is one of the reasons why there is variation in the rice area cultivated every year.

A major solution to the labor/power shortage is a certain degree of farm mechanization. At present, only 4% the households have their own farm machine. Development of cheap and efficient farm machinery and small farm tools that will reduce drudgery in rice cultivation especially for woman-farmers is a major challenge for the Agricultural Machinery Center.

9.8. Seed constraints

A land race is expected to exhibit uneven stand because it is composed of genetically diverse homozygous genotypes. In contrast, a released variety should be homogeneous since it is a pure line. Uniformity in crop stand of released varieties is observed in the research stations visited. However, released varieties grown by farmers exhibit non-uniformity in height and growth duration, indicating genetic impurity or mixture. Yield is reduced because of uneven competitive ability for light between tall and shorter plants. Management practices such as correct timing of fertilizer application and harvesting become a problem when plants differ in growth duration. The quantity and quality of the harvest is reduced when immature and mature grains are harvested together.

Table 15. Mean of labor and bullock requirements for different cultural operations.

Operation	Labor		Bullock
	man-days/ha	% of total	(pair-day/ha)
Land preparation	54.3	14.0	29.6
Sowing	4.9	1.3	2.5
Nursery management	7.4	1.9	-
Transplanting	46.9	12.1	17.3
Irrigation management	32.1	8.3	-
Weeding	44.5	11.5	-
Crop guarding	148.2	38.2	-
Harvesting	29.6	7.6	-
Threshing and cleaning	22.2	5.7	-
Total	387.8	100.0	49.4

Data source: 2003 Survey Report

In Cambodia and the Philippines, a 20% yield increase can be achieved in a given variety by just replacing impure with pure seeds. Farmers recognize the advantage of pure seeds but are constrained by their availability. The demand for pure seeds is more felt in areas where there is good control of water. Thus, there is a need to intensity the promotion and sale of certified seeds. Research stations are responsible for the production and maintenance of nucleus and breeder seeds while Druk Seed Corporation produces commercial seeds through contract growers. The seed supply and demand problem should be tackled just like the other agricultural inputs (fertilizer, fungicides, etc) (see topics 8.2 and 9.2).

10. Resource allocation and priorities

An attempt was made to determine the relative allocation of resources to the various research components of the rice research program across and within RNRRCs utilizing the data indicated in the centers' annual reports available at RNRRC-Bajo and Bhur Subcenter. For RNRRC-Bajo, information was based on five annual reports (2000-01 to 2005-06); RNRRC-Jakar, five (2001-2004, 2005-06); and RNRRC-Wengkhar, four (2000-01, 2002-05) and RNRRC-Yusipang, three (2002-05).

All RNRRCs conduct varietal improvement, crop management, post-harvest and socio-economics studies for agroecological zones within their geographical domains. Most efforts are directed towards varietal improvement, making it the flagship research program on rice. The RNRRC-Bajo case is described below as an example. On the average, close to 200 varieties and breeding lines are evaluated in researcher-managed trials (advanced evaluation trial, initial evaluation trials, observational nurseries and germplasm characterization) per year in the station. The evaluation process needs at least 282 plots per year considering the replications involved. There are also large plots devoted to segregating populations for varietal development and to nucleus/breeder seed production. The on-farms trials and in-situ conservation, which are mostly done through BUCAP, involved several farmer-cooperators. In contrast, the crop management component involves an average of three experiments with few treatments per year and the social science component has even less activities.

For varietal improvement, allocation of resources was examined for the three agroecological zones. Table 16 shows the research sites involved in researcher-managed activities under each RNRRC. RNRRC-Bajor, RNRC-Yusipang and RNRRC-Jakar are the key testing centers for mid, high and low altitude zones, respectively, but they also conduct researcher-managed activities for other zones within their district assignments. There are three research sites for mid altitude (Bajo, Mithun and Wengkar), four for high altitude (Khasadraphu, Darla, Khangma and Bumthang) and two for low altitude zone (Limenthang and Bhur), suggesting that less resources are devoted to low altitude zone.

All RNRRCs conduct farmer-managed trials which encompass pre-production evaluation trial, production evaluation trial and participatory varietal selection, in various geogs. Many of the on-farm trials are implemented through BUCAP with RNRRC-Bajo having the most number of sites (three in mid altitude and two in high altitude zones). There are also BUCAP activities under RNRRC-Yusipang and RNRC-Wengkar but to a lesser extent. The low altitude zone is not represented in the BUCAP network, confirming the low attention given to altitude zone.

RNRRC-Bajo is involved in developing varieties for mid altitude zone at Bajo and Mithun Subcenter (Figure 15). It also handles the development of segregating populations in the early generations for high and low altitude zones. Advanced populations for high altitude zone are transferred to RNRRC-Yusipang's experimental site at Khasadraphu (Figure 16, 17 and 18) and Darla Subcenter (Figure 19) for further generation advance and final selection. In contrast, the early generation materials for low altitude zone are further screened in succeeding generations only in one site, that is at RNRRC-Jarkar's Bhur Subcenter. Moreover, the breeding program for the high altitude zone has been on-going successfully for years (two locally developed varieties released in Bhutan) before the breeding program for the low altitude zone started.

Table 16. Sites where each RNRRC conducts its own researcher-managed varietal improvement activities.[1]

Activity	RNRRC-Bajo	RNRRC-Yusipang	RNRRC-Wengkar	RNRRC-Jakar
Varietal yield trial				
Mid altitude	Bajo and Mithun	-	Wengkar	-
High altitude	-	Khasadraphu and Darla	Khangma	Bhumtang
Low altitude	-	-	Limenthang	Bhur
Varietal development				
Mid altitude	Bajo and Mithun	-	-	-
High altitude	Bajo	Khasadraphu and Darla	-	-
Low altitude	Bajo	-	-	Bhur
Blast screening	Bajo and Mithun	Khasadraphu and Darla	-	Bhur
Germplasm conservation	Bajo	Khasadraphu and Darla	Wengkar	Bhur
Seed production	Bajo and Mithun	Khasadraphu and Darla	Wengkar	Bumthang and Bhur

[1] RNRRC-Bajo is the lead center for midl altitude, RNRRC-Yusipang for high altitude and RNRRC-Jakar for low altitude zone.

Figure 15. Mithun Subcenter is actively involved in varietal evaluation of breeding lines for the humid subtropical zone.

Figure 16. Blast screening is conducted in the screenhouse at Khasadraphu experimental site of RNRRC-Yusipang.

Figure 17. Locally developed promising line for the high altitude zone being multiplied at Khasadraphu experimental site of RNRRC-Yusipang.


Figure 18. Research Officer Mumta Chettri-discusses the attributes of promising locally developed lines grown at Khasadraphu.

Figure 19. Darla Subcenter generates crosses in screenhouse (above) and evaluates locally developed breeding lines (below) for high altitude zone.

Around 200 varieties/breeding lines are evaluated in researcher-managed trials per year for mid altitude zone at Bajo. Bhur Subcenter handles only some 50 entries per year for low altitude zone. Furthermore, efforts in Bhur are divided almost equally between the irrigated and rainfed lowland rice ecosystems. All of the above information indicates that the mid altitude zone varietal improvement research has the highest allocation of resources. The high altitude zone research is a far second priority. The low altitude research, particularly the rainfed environment, has the least amount of resource allocation. This explains why the number of released varieties for the rainfed lowland environments has lagged behind the other ecosystems. There is a need to increase the allocation of resources for rainfed lowland varietal improvement research considering that it accounts for nearly 40% of the total rice area. By virtue of its area, any modest increase in yield would have a recognizable impact in the total rice production in Bhutan.

11. Conclusions and Recommendations

In the recent last two decades, substantial increase in rice productivity has been observed. However, the national self-sufficiency in domestic production is only about 68% at the household level. The demand for more rice will continuously increase at a rapid rate because of the high population growth, increase in household income and rapid movement of rural people to the urban areas where rice is the preferred staple food.

The rice research program has made significant contributions to increasing rice productivity in the country. Improved varieties and various crop management technology options have been disseminated all over the country. Released varieties have good yield potentials and diverse genetic background. Some varieties have long life span, reflecting the breeders' successful system of selection. The nationwide adoption rate of released varieties is around 60%. However, the adoption level at the low altitude zone (rainfed lowland rice environment) has lagged behind that of the mid and high altitude adoption rate.

The analysis of the allocation of research resources in varietal improvement has shown that most resources have been devoted to the favorable environments, the mid and high altitude zones. The high altitude zone which has around 10% of the total rice area has been given better attention than the rainfed lowland of the southern belt which represents nearly 40% of the total rice area. The rainfed lowland areas contribute only 32% to the national rice production. Increasing the productivity in the low altitude zone will definitely have a substantial impact in rice self sufficiency goal. **Therefore, the rice research program should allocate more resources to the rainfed lowland rice research to achieve the national goal of rice self sufficiency.**

The 2003 survey report has provided adequate basic information to understand the nature of the rainfed rice environments. Farming practices and rice productivity are constrained by the unpredictable onset, amount, distribution, duration and recession pattern of rainfall. This report has thoroughly discussed these issues along with the constraints to adoption of improved technologies, other problems that have not been given attention in the past, and interventions that go beyond the research function of the RNRRCs. **Given below is a basket of recommendations that aims to improve the rice productivity in the low altitude zone and at the same time sustain the gains in favorable mid dry subtropical and high altitude zones.**

11.1 Varietal improvement

Rice varietal improvement should continue as the flagship component of the rice research program. The breeding program should focus on the following:
Utilization of foreign introductions directly as varieties after extensive testing has been effectively employed by Bhutanse rice breeders from the very start of its varietal improvement research, focusing primarily on favorable environments. **The program should expand the germplasm acquisition from IRRI by including materials that would broaden its selection base for desirable attributes wanting in rainfed lowland areas.** These should include the following sets of materials: upland and aerobic rice nurseries which may have adaptation traits for alternate wetting and drying; upland and rainfed lowland drought tolerant breeding lines, blast resistant lines, and lines with tolerance to stemborer.

The program should continue to breed for modern varieties since introductions often do not have all the desirable attributes needed. Associated with this is devoting more efforts for rainfed lowland. The program can still request IRRI to develop base populations for selection parents have been defined by Bhutanese breeders while local capability in the south is not fully realized.
There is a need to define clearly and prioritize the desirable attributes that should be combined into a single variety. A suggested list of attributes and their priorities based on the productions and varietal adoption constraints for each agroecological zone is given in Table 17.

The varietal improvement research has long been focused on mid altitude zone and success has been felt strongly in the dry subtropical zone (average yield in Wangdue was 3.71 t/ha in 2004-05). However, the success is less pronounced in the humid dry subtropical zone (mean yield in Tsirang was 2.09 t/ha). **The mid altitude breeding should be slanted towards the humid subtropical zone requirements, of which blast is a major constraint.**

In areas where there is a strong linkage among researchers, farmers and extension personnel and where the station environment does not represent the targeted stress, **farmer participatory plant breeding (farmers growing and selecting specific plants or lines in their fields) should be tried.** However, it should be limited initially to advanced generations or breeding lines.

Farmer participatory varietal selection (PVS) is commonly conducted through on-farm variety trials conducted in farmers' fields under their own management practices. **PVS should be continued and expanded to include farmer participation in selecting varieties/advanced breeding being evaluated in research stations.**

In Cambodia where the rainfed environment is also harsh, success in yield improvement was accomplished by screening hundreds of local traditional varieties and then releasing the most outstanding ones. In Laos, traditional varieties are also being screened and released for cultivation in marginal uplands. **Bhutan should explore selection among and within landraces to come up with purelines whose performance and uniformity could be even better than modern varieties under adverse environments.** Such pureline selections need less number of years of testing than foreign introductions because of its inherent adaptability in Bhutan.

Table 17. Desirable attributes and their priorities[1] in breeding varieties targeting low, mid and high altitude zones.

Desirable attributes	Altitude		
	Low	Mid	High
High yield, responsive to moderate input	1	1	1
Stable yield	1	1	1
Early maturity	1	1	1
Intermediate height	1	2	2
Lodging resistance	1	2	2
Blast resistance	1	1	1
Drought tolerance			
Reproductive stage	1	-	-
Vegetative stage	2	-	-
Seedling vigor	2	-	1
Stemborer tolerance	3	3	3
Cold tolerance	-	2	1
Good panicle threshability	2	2	2
Good grain quality			
High milling recovery	2	2	2
Intermediate amylase	2	2	2
Good taste	2	2	2
Aromatic	3	3	3
Red pericarp	3	3	3
Short, bold grains	3	3	3
Weed competitive ability	3	3	3

[1] 1 = first priority and 3 = last priority. First priority means that the trait is critical in improving/stabilizing yield and/or that large genetic variability can be accessed worldwide.

In the absence of irrigation, drought will remain as the major abiotic stress that confronts rice farming in the southern belt. **Thus, the breeders should start**

immediately a screening program for drought tolerance. This could be done in farmers' fields if the station site is not a hot spot for drought.

There is an immediate need to have duplicate samples of all Bhutan's traditional varieties in the IRRI genebank for safe keeping. Rice germplasm in IRRI Genebank is under the auspices of the Food and Agriculture Organization and it conservation and distribution follows the International Treaty on Plant Genetic Resources for Food and Agriculture of which Bhutan is a Party.

11.2 Other research components

Varieties can not answer all the production problems. There is always a need to conduct complementary studies involving crop management, post harvest technology, farm mechanization, and social science and policy research that are farmer problem oriented.

Integrated nutrient management efforts should focus on these challenges: development of fertilizer recommendations that are more site-specific (soil type based) and promotion of pre-rice green manuring. Most soils in the rainfed lowland area have low nutrient and water holding capacity being sandy to sandy loam and highly eroded in nature.

There are two unidentified disease problems in the rainfed lowland areas that are commonly observed by farmers in recent years. **Integrated pest management should monitor closely emerging problems in the low altitude zone and possible second generation pest problems in the productive mid and high altitude areas.**

Technology recommendations being disseminated include the judicious use of commercial chemical inputs such as fertilizers, herbicide, and pesticides. Farmers who are willing to use the chemical options are confronted with input availability and cost. They also have problems on availability of certified seeds. **The socio-economics and policy research group should make an in-depth study on factors that disrupts the flow of inputs from the primary source (Druk Seed Corporation) to the end-users (farmers) via commission agents and extension personnel. Other researchable areas are farm credits and enhanced role for the private sector on sale of agricultural inputs.**

Competition can trigger the reduction of price and improve the delivery of inputs. In areas where high rice productivity in the field is achieved, one way of sustaining the gains is to block any further loss in grain quantity and quality associated with post harvest operations. **The major challenge that the post harvest research component should address is the development/search for affordable, economically efficient small dryers and milling equipment that would reduce the quantity of broken grains.**

The competition for farm labor is a now common problem in Bhutan. In the southern belt, this is further aggravated by delayed onset of monsoon, which means that every farmers has to complete their operations at the earliest time possible' **The Agricultural Machinery Center should find ways to alleviate the farm labor problem through the use of affordable simple machine and tools for labor intensive field operations.**

The rainfed lowland areas receive a lot of rainfall but its erratic pattern constraints rice production. **Studies on water impounding techniques should be explored.**

There are production constraints that call for high level interventions rather than research. These constraints are given below.

In rainfed lowland areas, crop guarding against vertebrate pests (elephants, monkeys, etc.) accounts for the largest labor requirement in rice production. **Because of the international and national commitment of Bhutan in biodiversity conservation, it is essential that a dialogue among concerned policy makers be held to find ways to safeguard the livelihood of farmers against vertebrate pests.**

There is a need for the government to asses fully the existing irrigation systems in the southern belt, taking into consideration the flood-/landslide-damaged and unstable water channels, and possibility of constructing of new channels to expand the number of households that will benefit from partial or full irrigation.

11.3 Partnership

RNRRC-Bajo has led the rice research program successfully because it has established strong partnership with other RNRRCs, Department of Agronomy's district extension offices and farmers in generating pro-farmer technologies. Multi-location evaluation of promising technologies on-farm have been proven effective in generating farmers' feedback that serve as a basis for technology modification or technology recommendation. **RNRRCs should now establish strong partnership with the Agricultural Machinery Center and National Post Harvest Center in the search/development of machinery/farm tools suited to Bhutan's subsistence farming conditions and in understanding and finding solutions to post harvest constraints.**

The rice research program has kept up with the recent advances in rice science and technology because of its strong collaboration with international and regional organizations with similar interests. **The strong linkage with IRRI should be maintained since it is still the major source of worldwide genetic variability for rice, new technologies, current literature, and opportunities for training and international workshops/conferences.** The following programs at IRRI that are relevant to Bhutan are as follows:

International Network for Genetic Evaluation of Rice – The type of nurseries/germplasm to be requested are given in topic 11.1. Instead of requesting a whole set of entries in a given nursery, specific materials can also be requested by specifying the attributes needed., e.g., 120-140 d growth duration, 120 cm tall, 22-25% amylose content.

Consortium for unfavorable environment (CURE) – The consortium aims to improve productivity and stability of rice production in unfavorable, rainfed rice environments through farmer participatory research and development on rice as an integral component of the livelihood systems of farmers. One of its working groups deals with drought-prone rainfed lowland and upland ecosystems, the major concern in the low altitude zone of Bhutan. Linking with CURE will be a great opportunity for learning from the experiences of other countries whose production problems are similar to that of Bhutan. Two projects that operate within CURE that generate technologies and information relevant to Bhutan are the IFAD funded project on Managing rice landscapes in marginal uplands for household food security and environmental sustainability and the Challenge Program on Water and Food funded project on Rice Landscape management for raising water productivity, conserving resources and improving livelihoods in upper catchments of the Mekong and Red River basins.

Rainfed lowland and upland rice drought-prone breeding program – This focuses on developing rice germplasm that are drought tolerant, early maturing and weed competitive.

Communication with individual scientists at IRRI whose expertise are relevant to Bhutan's production constraints can be contacted anytime.

The rice research program should explore possible collaboration with the Paris-based French Agricultural Research Center for International Development or *Centre de Cooperation Internationale en Recherche Agronomique pour le Développement* (CIRAD) which works in more than 50 countries worldwide on targeted research for developing countries. CIRAD has a strong program on rice breeding and the contact person is Dr. Nourallah Ahmadi (nourollah.ahmadi@cirad.fr). It has also a good program on plant genetic resources management (sustainable *in-situ* conservation and promotion, and participatory plant breeding) and the contact person is Dr. Hélène Joly (helene.joly@cirad.fr).

The Biodiversity Use and Conservation Asia Program (BUCAP), which is being implemented by South East Asia Regional Initiative for Community Empowerment (SEARICE) with funding from the Development Fund of Norway (NORAD), has its share of contribution in enhancing farmer participatory approach to research and development. Farmer field schools serve as venue by which participatory varietal selection, in-situ conservation, on-farm seed production and testing new crop management practices are implemented. **It is recommended that BUCAP be expanded to include sites in the unfavorable rainfed lowland areas.**

The Australian Center for International Agricultural Research has been funding rainfed lowland rice research by Dr. Shu Fukai, Professor (crop physiologist) at University of Queensland, in a number of rainfed lowland rice areas in Southeast Asia. His works encompass understanding genotypic difference for drought, cold and low fertility tolerance, drought screening, direct seeding, delayed transplanting, and agroecological characterization**. It is recommended that Dr. Fukai (s.fukai@uq.edu.au) be contacted for information exchange.**

11.4 Capacity improvement

Enhancing research in rainfed lowland of the southern belt is critical in improving substantially the rice productivity in the country. This would require an immediate attention on the research capacity of Bhur Subcenter at Gelephu, the main test location for the low altitude zone. It is strategically located, being at the center of the three districts (Samtse, Sarpang and Samdrupjongkhar) where the targeted rainfed lowland rice areas are concentrated. The subcenter has experimental fields where water can be controlled. This is an important requirement in screening rice germplasm under different regimes of moisture stress. The experimental area for rice is about 2 ha and there is a lot more potential areas for research expansion in its 14- ha site. Neighboring farmers' fields represent the typical rainfed lowland environment. It is adjacent to the Seed Druk Corporation office, thus the issues on seed availability can be tackled immediately. Its accessibility is an important factor in conducting participatory variety selection and field days involving farmers from other locations. The following recommendations are meant to enhance the research capacity in the low altitude zone. A recommendation is also given to improve the capacity for the unfavorable humid subtropical zone.

There is an immediate need to increase the number of research staff in the subcenter. At present, Bhur Subcenter has only one technical staff (research assistant) overseeing rice research. This is already inadequate to meet present research needs of the whole low altitude zone. It will be impossible to accomplish anything substantial if the rainfed lowland program is to be expanded. There should be an additional two research officers and three research assistants to conduct drought screening (new initiative), field evaluation of more and new types of germplasm, selection in segregating populations, participatory plant breeding and participatory varietal selection.

One advantage of Bhur Subcenter over the other rice research units is its absence of cold periods through out the year that could affect the growth and development of the rice plant. Hybridization work can be done anytime of the year. Thus, hybridization for all agroecological zone-based breeding programs and rapid generation advance can be centralized in Bhur Subcenter. **It is recommended that Bhur Subcenter should develop a screenhouse with a dark room for hybridization and rapid generation advance. Provisions for field/laboratory equipment and vehicles should be given consideration.**

It is recommended that staff participating or to be involved in rainfed lowland rice research should undergo short term training and study tours to improve their knowledge and skills. Rainfed lowland areas with similar conditions are in neighboring states of India and Nepal. Places where rainfed lowland drought screening is done extensively are Raipur in India, Ubon in Thailand, and IRRI in the Philippines, to cite a few. Training programs that can be availed at IRRI are farmer participatory research, rice breeding, pest management, nutrient management and experimental designs and analysis.

Mithun Subcenter represents the humid subtropical zone, which is unfavorable compared to the dry subtropical zone. Like the Bhur Subcenter, it is strategically located. Its rehabilitation (non-functional for a number of years) is essential in pushing the gains made in the mid altitude zone. Its rice research activities fall in the hands of a single research assistant. **An additional one staff each at the research officer and research assistant level is recommended.**

Poverty analysis conducted in 2003 established that the poverty line in Bhutan is Nu 740.36 per month. Around 31.7% of the population is poor. Poverty is primarily a rural phenomenon. About 38.3% of the rural population is poor against 4.2% of the urban population. The rainfed lowland rice yield in the southern belt is the lowest in the country. Some 46% of the households surveyed in 2003 in Samtse and Sarpang reported food shortage and around 45% reported just enough food even when supplemented with other cereals like maize, millet and wheat. Increasing rice productivity in the southern belt has a far-reaching impact in alleviating poverty, the main development theme of the National Field Crops Research Strategy and Program Tenth Five Year Plan (2008-2013).

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