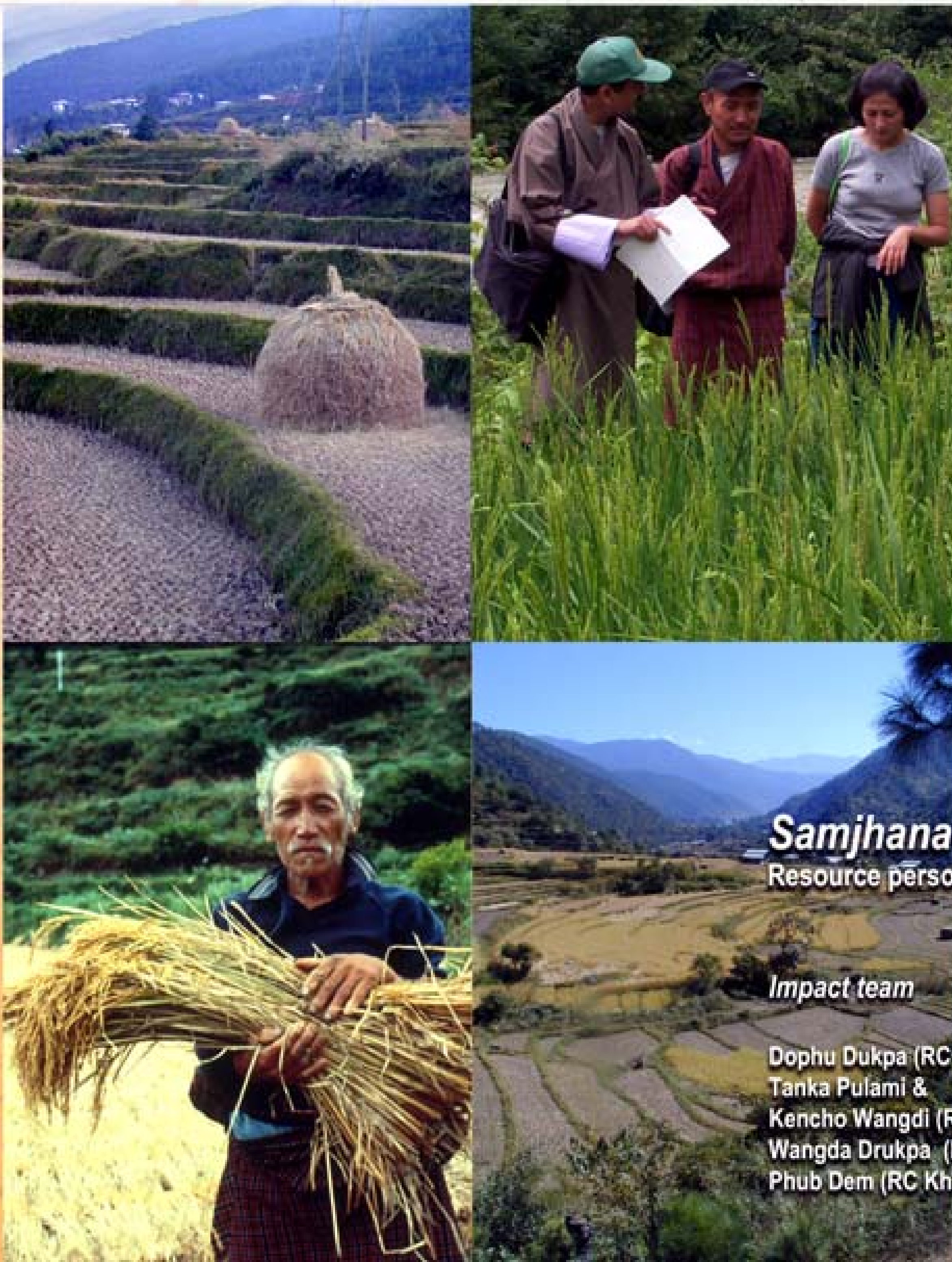
RNR Renewable Natural Resources
Ministry of Agriculture, Royal Government of Bhutan

An economic impact assessment of the rice research program in Bhutan



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A draft report

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Royal Government of Bhutan

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IDRC CRDI Canada

IRRI International Rice Research Institute

SDC Switzerland

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Acronyms

AVRDC	Asian Vegetable Research and Development Center
BMV	Bhutanese improved modern varieties of rice
CARD	Center for Agricultural Research and Development
CGIAR	Consultative Group on International Agricultural Research
CSO	Central Statistical Organization
DRDS	Department of Research and Development Services
ICARDA	International Center for Agricultural Research in the Dry Areas.
ICIMOD	International Center for Integrated Mountains
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Center
IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute
IMV	IRRI improved modern varieties of rice
INGER	International Network For Genetic Evaluation of Rice
IPGRI	International Plant Genetic Resources Institute
IPMO	International Programs Management Office
IRRI	International Rice Research Institute
ISNAR	International Service for National Agricultural Research
MOA	Ministry of Agriculture
MOU	Memorandum of understanding
MV	improved modern varieties of rice
NGO	nongovernmental Organizations
NRM	Natural resource management
OMV	Other improved modern varieties of rice
RGB	Royal Government of Bhutan
RNR-RCs	Renewable Natural Resources Research Centers
SAARC	South Asian Association for Regional Cooperation
SDC	Swiss agency for Development and Cooperation
TV	traditional varieties of rice

Nu	Ngultrum (nu), Bhutan’s currency, exchange rate is US$1 = Nu 44.

Acknowledgement

This report presents the results of impact assessment of the rice research program in Bhutan. The program was implemented by the Renewable Natural Resources Research Centers (RNR-RCs) of the Royal Government of Bhutan. The report is based on the information gathered from a number of sources including field survey conducted in November-December 2002, secondary agricultural statistics, interview with local and international officials working in the agriculture sector in Bhutan, and annual reports and documents of RNR-RCs.

It would not have been possible to uncover the success story of the rice research program without the cooperation and support of Mr. Sangay Duba (RNR-RC Bajo, Program Director) and Mr. Mahesh Ghimiray (Program Officer). We are grateful to the Program Directors of other RNR-RCs, Dr. Lungten Norbu (Yusipang), Mr. Kinzang Wangdi (Jakar) and Mr. Pirthiman L. Pradhan and Mr. Karma Tashi (Khangma) for their support in undertaking the study. We also would like to extend our appreciation to the staff of RNR-RC Bajo for their cooperation and general support during our trainings on impact assessment and during the preparation of the report.

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Executive summary

Formalized agricultural research in Bhutan started with the establishment of the Renewable Natural Resources Research Centers (RNR-RCs, formerly CARD) in 1982. There are four research centers in RNR-RCs, each with the national mandate on food crops, forestry, livestock and horticulture and the regional mandate on other sectors within their region. The RNR-RC Bajo has the national mandate for food crops and rice research is one of the major components of its program. The objectives of the rice research program are to develop improved rice technologies for raising productivity and farm incomes so that the national food objectives of 70% self-sufficiency in rice could be achieved. In addition, RNR-RC Bajo also has the responsibility to coordinate rice technology development, provide policy advice, and develop and manage linkages with national and international institutes.

This study reports on economic impacts of research and technology development conducted during the last two decades. In addition, institutional impact on capacity building for agricultural research is also briefly evaluated. The economic impact assessment is based mainly on farm survey conducted in seven main rice producing dzongkhags in November-December 2002.

The rice research and technology development program has been successful in increasing rice production and farm incomes, and improving food security. These benefits are likely to increase as rice technologies continue to spread over time. Some of the major impacts generated so far are as follows:

- Rice production during 1989 to 1997 increased by 58% even while rice area decreased by 9% during the period. The corresponding increase in yield by 75% was the main driving force for the production increase. As a result, the annual rice import stabilized, on average, at 33,000 t in recent years, despite the population growth.

- Improved rice technologies have led to an increase in national rice output by 5,000 t to 10, 000 t per year. Valued at the farm-gate price of Nu. 11,980 per ton, the estimated increase in gross valued output is between Nu 60 million and Nu 121 million per year.

- Net returns from the adoption of improved rice technologies are estimated at 9,000 Nu/ha. This translates to gain in net returns at the national level of Nu 58 million to Nu 118 million.

- Fifteen improved modern rice varieties (MV) have been released during the last two decades in Bhutan. Two of these varieties were elite lines developed at IRRI (IMV), seven were developed in other countries (OMV) and six varieties were developed specifically by the Bhutanese rice research program (BMV).

- The MV are now grown widely in all agro-ecological zones of Bhutan. At the national level, MV are grown by 60% of the households and cover 35% of the rice area.

- Various improved crop management practices were also developed and disseminated. The most commonly adopted improved management practices are improved methods for controlling weeds, application of inorganic fertilizers, improved land preparation and improved nursery preparation methods.

- The weighted average yield of MV is 27% higher than that of TV. The BMV outperformed all other groups of MV, indicating that these varieties are more suited to the local conditions. The BMV have the yield advantage of over 40% over the OMV. This is equivalent to the yield gain of 1.3 t/ha.

- Sixty-eight percentage of the households are now self-sufficient in rice. On average, the households who grow MV are less deficient in rice.

- The MV adopter households have 110% more cash income on average compared to the non-adopters. This higher cash income can be partly attributed to the improved rice productivity that enabled farmers to diversity to higher valued cash crops without sacrificing food security.

- The rice research program played a critical role in building the research capacity of the country. A total of 182 training opportunities, covering wide range of topics, were provided during the past two decades and the required infrastructures were developed. Planning, management and implementation of research programs have improved considerably and become stronger over time. In addition, RNR-RCs now provide critical inputs to national level planning and policy-making in agricultural sector.

1. Introduction

Rice is the preferred staple of Bhutan. Accordingly, the Royal Government of Bhutan (RGB) has placed a top priority for increasing rice productivity. Agricultural research and technology development in the country started in 1982 with the establishment of the Renewable Natural Resources Research Centers (RNR-RCs, formerly, the Center for Agricultural Research and Development). One of the primary objectives of these research centers is to generate rice technologies that would enhance productivity on a sustainable basis.

The main constraints to rice production in Bhutan are low soil fertility, prevalence of pest and diseases, cold temperature and high labor requirement for rice production (RNR-RC Bajo, 2001). Several rice technologies have been developed to overcome these constraints. Efforts have also been made in developing the infrastructure and human capacity for undertaking rice research. There are indications that these investments in rice research and capacity building have generated large gains (DRDS 2002). The success of rice research in the country is perceived as the role model and has provided the impetus on research for other commodities. The Joint Director of Research and Extension, Mr. Ganesh B. Chettri says "The benefits of research in the country is realized through the effective rice research program, and this model has been used in initiating research in other sectors for forestry, horticulture and livestock" (Personal communication, 2002).

Despite these positive indications of the impact of rice research, there has not been a systematic assessment of the impact of rice research in Bhutan. The purpose of this study is to assess the economic and institutional impact of RNR-RC's rice research program. The impact analysis reported here is based on the quantitative and qualitative data gathered for the study in 2002.

The report is organized as follows. First, a brief description of the institutional setup of RNR-RCs' and the objectives of rice research programs is presented. Second, main themes of the research programs, capacity building efforts and the nature of national and international collaboration are briefly described. This is followed by a discussion of the importance of rice in Bhutan and an analysis of recent trends in production and trade. A section on methodologies used for impact assessment study is subsequently presented. Finally, impact of rice research and technology is assessed in terms of increases in rice productions, gains in income, and achievements in food security, both at the farm and national levels. A brief assessment of the impact in terms of the institutional capacity building is also presented.

Many factors have contributed to the increase in rice production during the last two decades. Government's policies to increase food production, commitment by the extension agents to disseminate improved technologies to remote areas and investment in infrastructures are some of the examples. It is neither possible nor desirable to separate out contribution of individual factors involved in the development of the rice sector. The approach taken is to assess the overall impact in which RNR-RCs have played a critical role through rice research and technology development.

2. Renewable Natural Resources Research Centers

Institutionalized agricultural research in Bhutan started in 1982 with the establishment of the Center for Agricultural Research and Development (CARD). The CARD evolved to become the Renewable Natural Resources Research Centers (RNR-RCs) in 1992. The RNR-RCs' mandate is to improve the well being of the Bhutanese people on a sustainable basis through integrative research and development in agricultural, livestock, forestry and horticulture sectors.

The RNR-RCs has four research centers (RCs) located in Yusipang, Bajo, Jakar and Khangma. Each center has the national mandate for different renewable natural resource (RNR) sectors. In addition, each center also has the regional responsibility to undertake research in all RNR sectors relevant for its regional domain. Research in food crops is one of the major activities of all RNR-RCs.

2.1 Rice research objectives

The main objectives of the rice research program are to provide new and reliable information, technology, and materials to effectively overcome production constraints while raising farm productivity and income so that national food objectives can be attained. The major focus of rice research program is to conduct applied research to generate improved technologies. In addition the program is also involved in generating policy advice, managing and developing linkages with national and international institutes, and managing information and regulation on rice technology development (MOA 2000).

The RNR-RC Bajo has the national mandate to plan, manage and implement the rice research program. It formulates national strategic objectives and also provides technical support and guidance for regional rice research to other RCs. Its planning function is to ensure that rice research in all centers is consistent with the national and regional priorities, and complements each other while avoiding duplications. The test locations and leading RCs for different rice agro-ecological zones are shown in Table 1.

Table 1. Test locations for different rice agro-ecological zones.

Lead research center	Agro-ecological zone	Test location
RC Bajo	Medium altitude	Wangdue
RC Yusipang	High altitude	Thimphu/Paro
RC Bajo	Low altitude	Tsirang/Chukha
RC Jakar	Low altitude	Bhur

2.3. International collaboration for rice research

The RC Bajo also coordinates and takes a lead role in international collaborations and donor relations for rice research. The International Rice Research Institute (IRRI), based in the Philippines, has been the main international partner in rice research since 1984. This collaboration has contributed to building the required research infrastructure and knowledge base. The International Development Research Center (IDRC) of Canada has supported this international collaboration since 1984. The Swiss agency for Development and Cooperation (SDC) has co-financed the collaboration since 1995.

The RC Bajo also has links with the government institutes in the South Asian Association for Regional Cooperation (SAARC) member countries, Korea, Japan and Taiwan. Some of these countries have similar rice ecologies and hence, have also been the source of new rice technologies for local adaptations.

3. Major themes of the rice research and capacity building program

3.1. Varietal improvement

Initially, research focus of varietal improvement program had been developing and releasing cultivars with high yield potentials. In recent years, the focus has widened to include development of varieties that are resistant to rice pest, are cold tolerant and have locally preferred traits such as red pericarp[1]. Efforts at the conservation of local rice genetic materials to safeguard the gene pool for rice improvement in the future are also being undertaken.

3.1.1. Varietal introduction

Since 1985, Bhutanese rice scientists have been evaluating elite rice varieties from international and national institutes for local releases. These improved rice varieties go through rigorous evaluations prior to release in the county. For example, best elite lines are first evaluated on-station and further tested using on-farms trials in multi-locations. The on-farm evaluations consist of three stages, involving pre and post on-farm trials referred to as 'Researcher Managed Trial', 'Pre-production Evaluation Trial' and 'Production Evaluation Trial'. In these progressive stages of trials, ranges of suitable varieties are narrowed down and the nature of trials changes from researcher to farmer management (Chettri et al 1999). The varieties selected through this process are then sent to the National Seed Board for a final evaluation and official release.

3.1.2. Cross breeding

The main objective of the cross breeding program is to develop elite cultivars that would outperform the introduced improved varieties by overcoming the constraints specific to Bhutanese conditions. Under this program, major efforts were directed to developing rice varieties with high yield and red pericap. Other desirable traits that were incorporated into the cross breeding program were improved grain quality, ease of threshing, cold tolerance and resistance to rice diseases, especially the blast.

The outbreak of blast in 1995 devastated rice producers in the affected areas and highlighted the necessity of the cross breeding program. Local varieties were susceptible to blast and the

[1] Grains with red pericarp are considered as high quality rice in the high and medium altitude zones.

available improved varieties bred elsewhere were not tolerant to cold temperature. Hence, significant efforts were directed at deploying varieties that are blast-resistance, tolerant to cold temperature and adaptable the high altitude zone (1500 to 2600 meters).

3.1.3. Conservation of local rice germplasm

Recent efforts have also been directed to collecting and conserving local rice germplasm to safeguard the genetic pool. Both, *ex situ (*storage in gene banks) and *in situ* (conservation through sustained use on farmers fields) strategies are being utilized for conserving the rice genetic diversity. These activities are supported by the International Plant Genetic Resources Institute (IBPGR) and IRRI-SDC projects. The PGR conservation project supported by the Norwegian Development Fund is expected to strengthen this effort.

3.2. Crop management

The research on crop management includes the management of nutrients, weeds, pests and diseases, and crop establishment and improvement of the cropping patterns. These component technologies are briefly described below.

3.2.1. Nutrient management

The research efforts at improving soil nutrient management include appropriate level of application of organic and inorganic fertilizers, analysis of soil texture, appropriate use of tillage systems, and replenishment of soil fertility through green manure crops (*Sesbania aculeate* and *Astragalus sinicus*). As the main fertilizer used is still organic, extensive studies on the content and availability of organic fertilizers from community forest (forest litter) and domestic sources (from livestock and crop residue) have been conducted.

Intensive research on the responses of traditional and improved rice varieties to organic and inorganic fertilizers has been undertaken for different rice agro-ecologies. Recommendations for NPK, both in combination with organic fertilizers and separately, have been formulated for different parts of the country.

Farmers' use of inorganic fertilizers is reported to have increased over the years. In response to this and to stimulate further growth in rice production, research has also been undertaken to improve the yield response of popular rice varieties for different altitudes. Efforts are also underway to study the long-term effects of integrated plant nutrient management systems on rice and rice-based crops rotation systems.

3.2.2. Weed management

Identification and documentation of common weeds in rice production by different altitudes are being conducted as part of the weed management program. Weed management methods such as hand-weeding, mechanical control, changes in agronomic practices and chemical use are being evaluated.

In the high and medium altitude zones, the *Potamogeton distinctus* (locally called sochum) remains the most problematic weed and is estimated to reduce rice production by around 37% (Ghimiray 1999). Two chemicals effective against sochum were identified but their cost were prohibited. The current technical recommendation for controlling sochum problem is to conduct intensive hand-weeding and deep-ploughing.

3.2.3. Pest management

Rice diseases and insects, damage form wild animals and birds are some of the common pest problems. Major rice insects and diseases associated with rice both pre and post-harvest for different altitude zones have been identified and documented. Brown planthoppers, leaf hopper, neck and node blast, stem borer, sheath blight and seedling blast are the most problematic parasites. Improved varieties resistances to blast have been developed. For other parasites, research has focused on evaluating the protective methods, and monitoring. Some examples of the protective measures promoted are treating seeds to ensure that it is disease free, burning of infected straw and planting of susceptible rice varieties in wide and open valleys.

3.2.4. Agronomic practices

Several different component technologies for general agronomic management were evaluated. Some examples of the research programs are:

- Suitable planting times for different maturity-periods of rice varieties,
- Better nursery preparation methods, such as raised seed bed preparation, wet, semi-dry and dry bed, polytunnel seedling preparation, and appropriate level of seed rate use,
- Different tillage and crop establishment methods for efficient use of labor,
- Water management methods, and
- Rice ratooning.

3.2.5. Post-harvest management

Past studies on post-harvest management pertain to documenting current practices, identifying problems associated with grain storage in terms of pest and storages systems, preventing losses from post-production processes, and evaluating post-harvest technologies for labor saving during threshing and processing stage.

On-going and planned studies on post-harvest management include evaluation of rice varieties for non-shattering, identification of factors affecting head rice recovery in the period after the harvest and prior to storage, evaluating milling equipments for their effectiveness and efficiency in producing good grain quality, and selecting rice varieties with higher market value.

3.2.6. Cropping systems

Although multiple cropping is possible in almost all rice areas, rice-fallow farming systems is still common in Bhutan. Research focus in crop intensification has been mainly to fully utilize land for increasing and diversifying agricultural production. These programs have also been designed to improve soil nutrients through rotational cropping practices that include nutrient supplementing crops like legumes and green manure crops. The research focus has been mainly on identifying suitable varieties and appropriate management practices for rice and rice-based crops.

3.3. Infrastructure and human capacity building

Agricultural research in Bhutan commenced with rice research. The initial stages involved the setting up of the required physical infrastructure, skill building, developing plans, and strategies for research to undertake and implement a coordinated research program.

From the initial stages, enhancing human capacity was recognized as an essential component for achieving productive and sustainable research system. Capacity building activities involved short and long-term degree and non-degree training that included basic post school diplomas as well as university degrees. The training focused on wide-range of topics on rice science, integrated cropping systems, biodiversity conservations, research planning and management, computer skills, and community management of renewable natural resources.

In additions, staff participation in various study tours, seminars and national and international conferences were encouraged. Regular workshops were also organized between RCs for greater collaboration and integration of research programs.

4. Rice production patterns and trends in Bhutan

Increasing food production is one of the top national priorities in Bhutan. One of the targets of the ninth national plan (2002-07) is to achieve 70% self-sufficiency in food production. Food self-sufficiency is largely interpreted to mean self-sufficiency in rice (MOA 2000).

Rice area is classified into three distinct rice agro-ecologies specified as high, medium and low altitude zones. The high altitude zone is in the altitude range 1500 to 2600 meters and has a warm temperate climate. Medium altitude zone consists of valleys and foothills of Himalayas in the altitude between 600 to 1500 meters. The low altitude zone is mainly the southern rice belt with elevations between 160-600 meters. Generally, 20% of the rice area is classified as high altitude zone, with medium and low altitude zones accounting for 40% each.

The absence of a reliable national level data makes it difficult to ascertain the trend in rice production over time. The RNR Statistics is the official data source for agricultural related information. According to this database, Bhutan's rice area, production and yield in 2000 were over 19,000 ha, 44,000 t and 2.28 (t/ha) respectively (Table 2).

Table 2. Rice area, production and yield by dzongkhag and altitude zones, 2000.

Dzongkhag[1] (District)	Area (ha)	Production (t)	Yield (t/ha)
High altitude	**2,179**	**5,658**	**2.60**
Bumthang	27	45	1.64
Gasa	87	194	2.22
Ha	105	186	1.77
Paro	1,269	3,083	2.43
Thimphu	690	2,151	3.11
Medium altitude	**10,658**	**26,157**	**2.45**
Chhukha	722	1,262	1.75
Dagana	1,143	2,233	1.95
Lhuentse	760	1,967	2.59
Mongar	445	888	1.99
Pemagatshel	20	46	2.35
Punakha	1,971	6,274	3.18
Trashigang	941	2,440	2.59
Trongsa	554	1,157	2.09
Tsirang	1,473	3,067	2.08
Wangdue	1,467	4,024	2.74
Yangtse	630	1,763	2.80
Zhemgang	532	1,036	1.95
Low altitude	**6,558**	**12,484**	**1.90**
Samtse	2,889	4,650	1.61
Sarpang	2,839	5,830	2.05
S/Jongkhar	830	2004	2.41
National	**19,395**	**44,298**	**2.28**

Note: The rice growing environment is divided into three distinct zones and associated with particular dzongkhags. However, a dzongkhag could contain one or more rice altitude zones. The categorization of dzongkhags to different altitude zones is based on Eighth Five Year Plan for commodity program.

(Source: MAO 2001)

In addition to this official data source, there are also several data sources that are commonly used in RCs and by government officials at all levels. The estimates of rice area and production derived from these commonly used databases are presented in Table 3.

Table 3. Rice area, production and yield for different data sources.

Data sources	Area[a] (ha)	Production (t)	Yield (t/ha)
CSO database[b]	26,010	39,790	1.53
RNR Statistics (2000)	19,396	44,298	2.28
Cadastral survey (1999)	26,512	59,685	2.25
MOA (1997)[c]	23,679	63,065	2.66
GIS/LUPP (1995)	39,240	88,338	2.25
FAO database (2001)	30,000	50,000	1.67
Average	27,473	57,529	2.11

(Source: Full reference for the cited work, see in the Reference list).

[a]Rice area is recorded in net area planted to rice for all data sources except for the GIS/LUPP method for which it represents the gross area planted to rice.
[b]Agronomic survey conducted in 1988/89 cited in Statistical Year Book of Bhutan, for 1999 and 2001.
[c]Data cited in MOA (2000). This data base also has time series data for 1989-97.

The RNR database provides the lowest estimate of rice area and the second lowest estimate of production level. The rice area and production based on GIS/LUPP is almost twice the official estimates at over 39,000 ha and 88,000 t, respectively. The estimate based on the Cadastral survey is in the mid-range and is considered to be more realistic by researchers at RCs. As per the Cadastral survey estimate, Bhutan's rice area and production are over 26,000 ha and 60,000 t, respectively. There is also a time series database with area and production estimate close to the Cadastral survey (cited in MOA 2000). Based on this estimate, rice area decreased by around 9% during 1989 to 1997, but production and yield increased by over 58% and 74%, respectively during the same period.

Table 4. Rice area, production and yield, 1989-1997.

Year	Area (ha)	Production (ha)	Yield (t/ha)
1989	26,010	39,790	1.53
1990	26,304	59,449	2.26
1996	23,777	65,576	2.76
1997	23,679	63,065	2.66
Average	24,943	56,970	2.30
Difference between 1989 to 97	-9%	58.50%	74.10%

(Source: Data cited in MOA, 2000)

4.2. Rice self-sufficiency

There are several estimates of the national self-sufficiency level, the main ones are presented in Table 5. These different data sources indicate that domestic production fulfills 40 to 65% of the requirement. The remaining requirement is met by imports. India is the major source of imported rice.

Table 5. National self-sufficiency in rice.

Data sources	**Self-sufficiency (%)**
RNR Statistics (2000)	39
Cadastral survey (1999)	46
MOA (1997)[3]	56
GIS/LUPP (1995)	56

(Sources: Full reference for the cited work, see the Reference list).

The Food Corporation of Bhutan (FCB) and private enterprises are the main importing agencies. Between, 1995 to 2000, the rice import averaged approximately at 33,000 t per year (Table 6). There is only a slight variation in imported quantity among these years.

Table 6. Rice import to Bhutan (tons), 1995-2000.

Year	FCB import (t)[a]	Total import (t)[b]
1995	11,780	31,227
1996	13,392	29,237
1997	15,862	29,026
1998	9,005	34,816
1999	13,226	38,709
2000	6,302	33,704
Average	11,594	32,787

(Source: Food Corporation of Bhutan cited in CSO 2001[a] and Bhutan Trade Statistics, MOA 2000)[b].

Note: The FBC is a government cooperative institute. Rice imported through this channel is subsidized and based on quota agreement with India.

A relatively stable level of import indicates that domestic supply has largely kept pace with the increased demand for rice over time. Available farm level studies also support the notion that food availability has improved over time in rural areas. For example, household level studies in Wandgdu-Punakha valley indicate that rice surplus increased from 13% in 1992 to 40% recently (MOA 2000). As per the RNR Statistic in 2000, around 44% of the households have attained self-sufficiency in food (MAO 2001).

On average, the national food shortage is estimated at 2.2 months. The statistics on household food shortage and their coping strategies by dzongkhag and altitude is presented in Appendix 1.

4.3. Future rice demand

Traditionally, rice was produced and consumed mainly in the Western and Southern regions of Bhutan. Over time, rice has become a major staple in most parts of the country. Currently, it is the staple crop of over 65% of the population. It is also the preferred cereal crop of people whose current diet is non-rice based. In the Western and Southern regions, per capita milled rice consumption is one of the highest in the world at 167 to 262 kg per year (MAO 2000 and 2001, GIS/LUPP 1995, and Cadastral survey 1990), respectively.

The demand for rice is expected to increase in future, driven mainly by factors such as growth in population of around 3% per annum, increase in income, and rapid urbanization. With increase in incomes, Bhutanese are increasing the consumption of rice –a preferred staple in urban and rural areas. Current urban population estimated at 20% is expected to increase at the annual rate of 6 to 7 % during the next 20 years. This is expected to contribute to increasing demand for rice since increase in urban population is positively correlated rice consumption (MOA 2000).

5. Methodology for impact assessment

Impact assessment is a process of estimating whether or not research, technology development, and capacity building efforts have produced their intended effects in meeting the development objectives (Anderson and Herdt 1990). The assessment can be ex ante or ex post. The ex ante assessment is conducted prior to the project implementation to estimate the likely impact on the target population. The ex post impact assessment measures the actual benefits realized.

The outputs of rice research are new and improved varieties, better crop management practices and enhanced human capacity for research and development. These outputs have direct, indirect and intermediate impacts. The direct impact refers to the impact on the welfare of people and environment as a result of adoption of a technology. It is measured mainly as the increase in productivity, reduction in per unit cost of production, and/or reduced pressure for expansion into fragile ecosystems. Indirect impact includes flow-on impacts to other crops and activities. An example of indirect impact would be diversification to high value cash crops as rice requirements are fulfilled. Intermediate impact refers to increases in the knowledge base that could subsequently generate direct impact. For example, information on the evaluation of the gene pool, prototype technologies, and new skills and knowledge of researchers are intermediate benefits.

5.1. Economic surplus model

An economic surplus model is widely used in quantifying the returns to investment in agricultural research (Aston and Pardey 1995). The method is based on quantifying the increases in consumer and producer surpluses arising from the adoption of new technologies. This is the basic conceptual framework utilized in this study for impact assessment. A short description of the framework is provided here. For details please see Shrestha et al (2002).

Figure 1 illustrates the basic framework. Initially, with the existing technique, Q_0 is produced at the P_0 price level on the supply curve S_0. The adoption of a new technology results in a shift in the supply curve from S_0 to S_1. As a result, rice production increases from Q_0 to Q_1 and the price is reduced from P_0 to P_1.

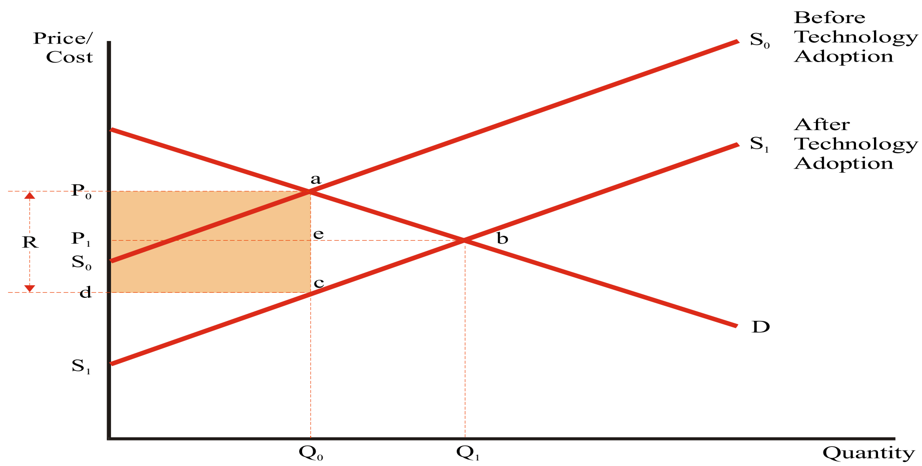

Figure 1: The supply and demand model of research benefits.

The benefits to consumers and producers of the improved technology are

- Consumers benefit because they can purchase more output at a lower price. This increase in consumer surplus can be estimated by the area P_0abP_1.
- Producers' benefit from higher output and a decline in the unit production cost. This benefit can be estimated by the area P_1bcd.

The total benefit from the research program is the sum of the producers and consumers' surplus. The rectangle area P_0acd is often a close approximation because the triangle abc is relatively small. The distribution of the total benefit between producers and consumers depends on the size of the fall in price (change in P) relative to the fall in cost (R). In turn, this depends on the elasticities (slopes) of the supply and demand curves. When the absolute values of the elasticities are equal, the benefits from research are shared equally between producers and consumers.

5.2. Data sources and sampling procedures

Impact assessment conducted in this study is based on both the quantitative and qualitative data. Primary data were collected through a household survey and secondary data were obtained from national statistics, RNR-RCs documents and other publications. Qualitative data were collected from various stakeholders through personal interviews and focus group meetings.

A farm household survey was conducted in November-December 2002 (a 'normal' year for rice production), soon after the harvest season. The survey included information on summer and winter crops. The household heads were interviewed using structured questionnaires to generate the required data (Appendix 2).

A stratified multistage random sampling method was used to draw representative samples. Seven main rice producing dzongkhags from high, medium and low rice altitude zones were selected. These dzongkhags accounts for 62% of total rice area and 64% of rice production in Bhutan (Appendix 3).

Twenty-seven Goegs (blocks) were selected from these dzongkhags in consultation with RNR-RCs staff and district government officials. These geogs were selected to represent different conditions such as access to markets, distance from road, distance from the research centers, and farm size. The villages and households were then randomly selected from these geogs from the records of the dzongkhag offices. A total of 248 households samples from 104 villages were selected. The names of the dzongkhags by altitude and their corresponding number of geogs, villages and households are illustrated in Table 7. (see Appendix 4, for geogs and villages included).

Table 7. Dzongkhags, geogs and villages included in the impact assessment survey, 2002.

Altitude/ Dzongkhag	Number of Geog	Number of Village	Sample Size
Low			**60**
Samtse	4	19	40
Sarapang	2	8	20
Medium			**83**
Punakha	3	6	30
Sarapang	1	5	10
Trashigang	4	21	33
Wangdue	1	3	10
High			**105**
Paro	5	19	50
Thimphu	2	11	21
Trashigang	3	10	14
Wangdue	2	5	20
Total	**27**	**107**	**248**

(Source: Impact assessment survey, 2002)

Note: High altitude zone = above 1,500 to 2,600 meters, medium altitude zone = above 600 to 1500 meters and low altitude zone = from 160 to 600 meters. Some geogs and villages in Trashigang, Sarpang and Wangdue are represented in two altitude zones.

The main sources of quantitative secondary information were the annual and technical reports of RNR-RCs and other government documents, UN and IRRI publications and database. The MAO data (2001), RNR statistics, is the official data source for agricultural statistics. There are several other databases also. Considerable difference exits in estimated statistics between these data sources. The research group favors the data based on the Cadastral survey method and hence, it is the main data source used in this study to estimate the impact of research and technology development.

Qualitative data were gathered from RNR-RCs staff, high level officials from central and district offices from agriculture, extension, marketing and training centers, donor community and international research partners (see list in Appendix 5). Focus group meetings and interviews were used to solicit the information. The interviews were focused on identifying the research programs that have had the most impact, on assessing the integration of research and extension in delivering research findings and in identifying research programs that are likely to have substantial impact in the future. Subjective assessments of the impact of RNR-RCs were also obtained from these interviews.

The resource person (Consultant in impact assessment) was mainly responsible for designing the survey, training the impact team (RNR-RCs staff), gathering information for subjective assessment, analyzing the data, and writing up the report. The impact team coordinated the survey and compiled the data (see Appendix 6 for the list of enumerators).

5.2. Indicators of impact for the study

The benefits generated by RNR-RCs' rice research program are assessed here using the following indicators:

- number of rice varieties released and crop management practices developed,
- extent of adoption of improved new rice technologies,
- magnitude of yield gain and increase in the value of production,
- increase in net income of farmers,
- increase in household cash income,
- achievement of rice self-sufficiency, and
- improvement in general welfare.

General assessment of the capacity building efforts was also undertaken. The indicators used in assessing the institutional impact are:

- number of people trained,
- effectiveness in disseminating research findings,
- effectiveness in research planning and implementation, and
- number of network developed within the country and internationally.

6. Assessing research and capacity building impact

During the last two decades, the rice research system of Bhutan has evolved substantially. The early activities were focused on conceptualizing and identifying research program, establishing infrastructure and developing human capacity for research. The research system has now focused on developing and testing technology packages some of which are now widely adopted across the country.

6.1. Release of improved varieties

Fifteen improved rice varieties have been officially released. The names of the varieties, year released, their main traits, and suitability to different altitude zones are presented in Table 8. The released varieties have been categorized in three groups, namely IRRI MV (IMV), Other MV (OMV) and Bhutanese MV (BMV). The IMV are defined here as improved varieties that were developed at IRRI and directly released in Bhutan after screening. The OMV are mainly improved varieties developed in countries such as Bangladesh, India, Japan, Korea, Nepal, and Sri Lanka. Some of these varieties were obtained through the International Network For Genetic Evaluation Rice (INGER) managed by IRRI. The BMV are crossbred varieties between Bhutanese TV and IRRI's elite cultivars bred specifically for local agro-ecologies.

Table 8. Nationally released modern varieties of rice in Bhutan, 2002.

Modern rice varieties	Year released	Released for altitude	Traits
IRRI's improved varieties (IMV)			
IR 64	1988	Medium	White and good grain quality, semi-dwarf, 80-90 cm tall.
IR20913	1989	Medium	100 cm tall, matures in about 130-140 days.
Other modern varieties (OMV)			
Milyang 54	1989	Medium	White grains, 95 cm tall., Matures in 140-145 days, cold tolerant.
No. 11	1989	High	Cold tolerant, early maturing, 90 cm in height, matures in 160 days.
BR153	1989	Low	White grains, 100-110 cm tall, matures in 140-150 days.
BW 293	1990	Low	75-85 cm tall, matures in 140-150 days, slender white grains.
Barket	1992	Medium	Cold tolerant, high yielding, early maturing, 90-95 cm in height, matures in 155 days.
Khangma maap	1999	High	Red grains, 90-100 cm tall, matures in 120-130 days, blast resistant.
Khumal 2	2002	Medium	
Bhutanese modern varieties (BMV)			
Bajo maap 1	1999	Medium	Red grains, 100-105 cm tall, matures in 150-155 days, resistant to lodging.
Bajo maap 2	1999	Medium	Red grains, 100-110 cm tall, matures in 145 days, tolerant to blast and stem borer.
Bajo kaap 1	1999	Medium	White grains, 95-155 cm tall, matures in 145-155 days, resistant to lodging.
Bajo kaap 2	1999	Medium	White grains, 90-100 cm tall, matures in 150-155 days.
Yusi ray maap	2002	High	Red grains, 115-120cm tall, matures in 170-180 days.
Yusi ray kaap	2002	High	White grains,90-95 cm tall, matures in 170-180 days.

(Source: RNR-RC Bajo 2001, Ghimiray and Pradhan 2002).

The OMV and IMV were evaluated in the varietal introduction program of Bhutan (see Section 3.1.1.). Khangma maap (locally known as Chumrro is from Nepal) is one of OMV group of rice variety officially released after local selection as it possessed major desirable traits (resistance to blast, with red pericarp and adaptable to high altitude). The variety BR 153 was selected for its adaptability to low fertile soils with erosion that characterize the low altitude zone.

The BMV have locally preferred traits such as red grains, resistance to blast and shorter maturity period. For example, the Bajo Maap 2 is a crossbreed between IR 64 and TV that is highly valued for its red-pericarp. These are relatively new varieties released less than five years ago.

Of the 15 released varieties, nine varieties were released for the medium altitude zone, four for the high altitude zone and two were for the low altitude zone. Some of these varieties are being grown now outside their target zone also. The improved released varieties Barket, No. 11 and IR 20913 are recommended in double rice cropping also.

In addition to these varietal releases, the varietal improvement program also accomplished the following. Some highlights of research outputs are presented below.

- More than 6,000 elite lines from IRRI and others countries have been evaluated at research centers and, of these, more than 300 entries were tested on farmers' fields.

- Some 5,740 breeding lines have been crossbred involving Bhutanese TV and improved breeding lines (list in Appendix 7). Over 140 crosses have been generated that show excellent performance in terms of suitability to local conditions with superior performance compared to the varieties that are currently in use.

- Some 400 accessions have been collected from major rice growing regions of Bhutan. These are the working samples for RC Bajo. There have been sent to IRRI Genebank for safekeeping. A copy of these accessions will also be kept in the national germplasm bank currently being developed in Thimphu.

- Additional 1,000 pedigree lines have been collected. There will be evaluated, characterized and tested on-farms (DRDS 2002).

6.2. Highlights of crop management and cropping systems research

Several complementary crop management technologies have been developed also. These technologies are designed for rice and rice-based cropping systems. Some of the highlights are as follows.

- Different packages for raising nursery in semi-dry bed, dry bed, wet bed and polytunnel methods were developed.

  Semi-dry and dry method: bed size of 1m x 3m, raised to 10-13 cm, 3 Kg organic and seed rate of one 1.24 kg seeds for 1m x 6m bed is recommended for semi-dry nursery preparation. For the dry bed nursery preparation, same procedures are to be followed without raising the bed.

  Wet-bed method: seeds are to be soaked in water for 24 to 36 hours, incubated for 36 to 48 hours and the pre-germinated seeds broadcasted. 1.24 kg of seed is recommended for 1m x 6m seedbed.

  Polytunnel method: recommended for first crop in rice double cropping.

- Fertilizer recommendations for different dzongkhags for TV and MV have been developed (Appendix 8).

- Two species of green manure Dhaincha (*Sesbania aculeata*) and Chinese milk vetch (*Astragalus sinicus*) identified as suitable green manure crops. The first type is recommended for altitude in the range of 150-1300 meters. The second is recommended for altitude above 1300 meters for winter crop.

- The released varieties were accompanied with comprehensive instruction on suitability to different altitudes, field preparation methods, nursery sowing, transplanting and harvesting time and with other details. The pamphlets prepared for extension agents illustrate the details (Appendix 9).

- Several recommendations for crop intensifications through double cropping of rice and rice with other crops, legumes and vegetables were developed. The varieties specified for crop intensification with appropriate management practices are illustrated in Appendix 10.

- Recommendations for rice ratooning for area with adequate water supply is presented in Appendix 11.

- Effective chemicals to control sochum, sanbird and NC 311 have been identified. Other control measures are being developed to reduce the cost of control.

- One of the strategies pursued in reducing labor requirement in rice production was by developing direct seeding method of crop establishment (Appendix 12).

- Grain moth (*Sitotroga cerealella*) and grain weevil (*Sitophilus oryzae*) were identified as two main rice insects problems during storage.

- IPM leaflets on blast have been developed and disseminated to the farmers through extension agents. Several management practices were also released which include using disease free seed, proper water management and burning infected straw.

- The prevailing practices in various aspects of the rice production from field preparation to grain storage methods were studies. The effective prevailing practices such as sealing the top of the basket with a thick cap of dung or mud for storing grains were hailed and supported.

- Several crop/vegetables rotation practices have been developed to replace rice-fallow farming systems. The main rotational packages consist of rice double cropping, rice-wheat, rice-mustard, rice–vegetables and rice-green manure.

6.3. Farm level analysis

There is high degree of uniformity across the different altitude zones among the 248 households survey in terms of family size, age of the households' head, attainment of formal education and experience in farming of the household heads, and gender responsibility in farm households managements (Table 9). The average household size is approximately 8 per persons and women are the heads 40% of the households. Farming is the main occupation for over 90% of the households. The average age of the household head is approximately 50 years and over 80% of them do not have formal educations.

Table 9. Profile of the surveyed households, 2002.

Altitude	Family size	Information on the household head			
		Farmer's age	Female head (%)	Non-formal education (%)	Farming main occupation (%)
	average	average			
High	8.4	51.0	46.7	84.8	94.3
Medium	8.1	55.6	38.6	78.3	95.2
Low	7.5	49.0	33.3	86.7	98.3
Overall	8.1	51.5	40.7	83.1	95.6

(Source: Impact assessment survey, 2002)

The farm households own both dry and wet lands (see Appendix 13). The survey data indicated that rice is cultivated in the wetlands only. Overall, approximately, 98% of the wetland is planted to rice (Table 10). In the medium altitude zone, 100% of the wetlands is planted to rice while small portions of the wetlands in the high (2.3%) and the low (4.8%) altitude zones were not planted to rice.

Table 10. Wetlands rice area and farm size, 2002.

Altitude	% of wetland		Average wetland farm size (ha)
	Rice	Non-rice	
High	97.7	2.3	0.27
Medium	100.0	0.0	0.22
Low	95.2	4.8	0.77
Overall	97.5	2.5	0.32

(Source: Impact assessment survey, 2002).

The average wetland farm size of the surveyed households is estimated at 0.32 ha. The farm sizes in the high (0.27 ha) and medium (0.22 ha) altitude zones are relatively small compared to the farm size in the low altitude zone (0.77 ha).

6.3.1. Adoption of modern rice varieties at household level

Households often cultivate both modern and traditional rice varieties. Households who cultivate MV in a part of their farm are considered as adopters here. Overall, approximately 60% of the surveyed households have adopted MV of rice. The adoption rate is highest at 77% in the high altitude zone, followed by medium (59%) and low (32%) altitude zones (Table 11).

Table 11. MV adoption at the household level, 2002.

Altitude	% of households	
	MV adopter	MV non-adopter
High	77.1	22.9
Medium	58.5	41.5
Low	31.7	68.3
Overall	59.9	40.1

(Source: Impact assessment survey, 2002)

The data was disaggregated further to study the percentage of households who adopt only MV and a combination of MV and TV (Appendix 14). The high altitude zone has the highest percentage of households adopting MV only (46%). In the medium altitude zone, approximately, 42% of the households plant both TV and MV. Some 17% of the households adopted MV only. In the low altitude zone, over 68% of the households have not adopted MV of rice.

The MV adoption pattern during the last two decades by altitude is illustrated in Figure 2. Percentage of households adopting MV in each year was cumulated to obtain the values in the vertical axis. The figure illustrates that there was a gradual increase in the cumulative percentage of adopters during initial stages for all altitude zones during 1989-1993. From 1994 to 1998, the MV adoption rate accelerated in the high and medium altitude zones. During this period, the MV adoption increased in the Low altitude zone also but the rate of adoption lagged behind. Since 1998, the adoption of MV slowed down as over 90% of the households adopted MV.

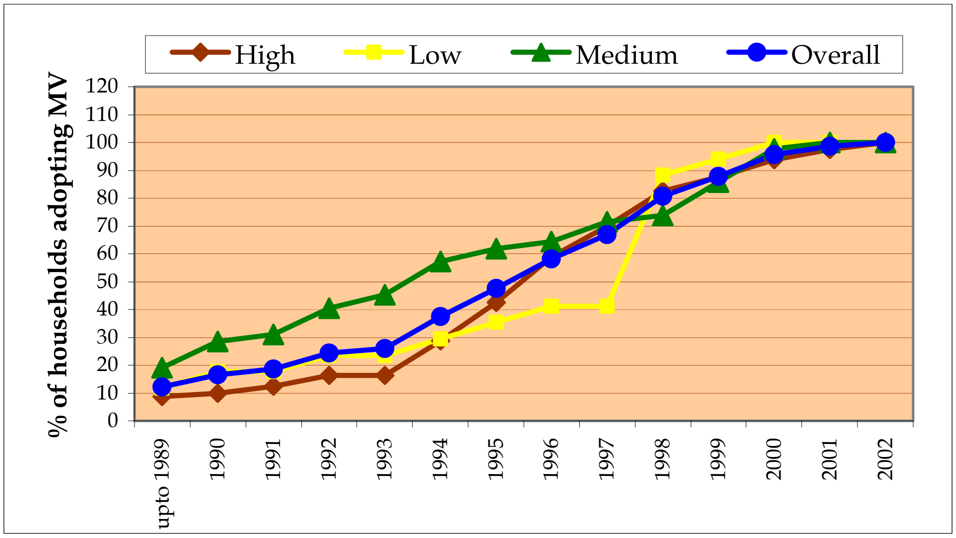

Figure 2. Cumulative MV adoption patterns, 1989-2002.

6.3.2. Rice cropping intensity

Only 6% of the surveyed households planted rice as a second crop in the winter season. Most of these households (67%) were from the Medium altitude zones. The IR 20913 was the most commonly planted MV of rice during the winter season.

Double cropping of rice in Bhutan declined considerably since the 1990s. This is confirmed by the focus group meeting with extension agents and research staff from the medium altitude zone where double rice cropping was most prevalent. (Personal communication, see Appendix 5). The main reasons for the decline are stated as follows:

- lack of assured irrigation,
- general decline in community adoption hence it suffers heavy losses from birds, rats, and livestock,
- general improvement in household rice self-sufficiency, and
- increased diversification to high value cash crops.

The last two factors suggest that there is a direct correlation between increased rice production and reduction in double rice cropping. For example in Rinchengang, a severe rice deficit village, three out of the four households continued double rice cropping.

In a society that is in the transition from subsistence to semi-subsistence, households diversify their livelihood strategies. As rice production increased due to the adoption of MV, only one crop of rice became adequate to meet the family food needs. Hence, farmers were able to diversity to higher valued cash crops during the second season without sacrificing food security.

6.3.3. Area adopted to modern rice varieties

Overall, approximately 35% of the rice area is planted to MV of rice (Table 12 graphically illustrated in Appendix 15). There is, however, a considerable difference in MV area across the three altitude zones. The high altitude zone has over 66% of rice area planted to MV compared to only about 17% in the low altitude zone. In the medium altitude zone, almost 38% of the rice area is planted to MV.

Table 12. Rice area under different groups of rice varieties, 2002.

Altitude	% Wetland rice area under	
	TV	MV
High	33.8	66.2
Medium	62.5	37.5
Low	83.3	16.7
Overall [a]	65.1	34.9

(Source: Impact assessment survey, 2002)

[a] The area adopted to MV for the overall estimations is derived by assigning weights (high altitude zone 20% and 40% each to the medium and low altitude zones) according to the composition of the national rice area.

The rice area under different groups of MV by altitude is presented in Table 13. The OMV is the most popular of the three groups of MV adopted. It is planted in over 60% of the area adopted to MV. In the high and low altitude zones, OMV is the most dominant MV and is planted to over 90% of the MV rice area.

Table 13. Adoption of different groups of MV of rice, 2002.

Altitude	% MV rice area under		
	BMV	IMV	OMV
High	2.8	0.7	96.5
Medium	15.8	72.8	11.3
Low	0.0	8.7	91.3
Overall [a]	6.9	32.8	60.4

(Source: Impact assessment survey, 2002)

[a] The overall estimation has been assigned weights as per the Table 12 .

The second most commonly planted group of MV is IMV. The IMV accounts for 33% of MV rice area and it is mostly planted in the medium altitude zone (73%). In the low altitude zone, IMV account for only 9% of MV rice area.

The BMV are planted to approximately 7% of MV rice area, with most of it being in the medium altitude and some in the high altitude zone. The BMV are relatively new varieties, which were released less than five years ago. Two of the six varieties in BMV were released only a year ago.

In summary, the high altitude zone is planted mostly to OMV, the medium altitude is planted to IMV and some BMV, and the low altitude is planted to OMV and IMV (Figure 3).

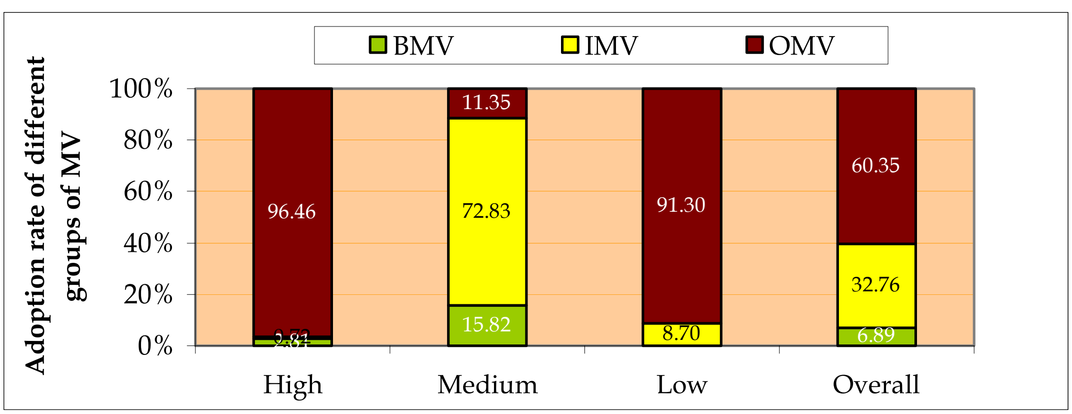

Figure 3. Adoption of different groups of modern rice varieties by altitude, 2002.

Of the 15 varieties released, only 11 varieties have been grown widely. The most popularly adopted varieties are Khangma Maap, No 11, IR 64, Bajo Kaap 1 &2 and Bajo Maap 1 &2. Only one of the released BMV is not adopted (i.e. Yusi Ray Kaap) and three varieties (Barket, BW 293 and Milyang 54) from OMV were also not adopted. The percentage of area allocated to each of the variety by altitude is presented in Appendix 16.

6.3.4. Adoption of improved crop management practices

Along with the adoption of MV of rice, the survey data indicated that there has also been partial adoption of several other rice technologies. The adoption of various improved crop management practices ranges from approximately 8% to 60% (Table 14). The most commonly adopted management practices are for controlling weed (60%), application of inorganic fertilizers (58%), land preparation (42%), mechanization (37%) and improved nursery (24%). Other crop management practices, such as improved planting methods, pest control have had limited adoption.

Table 14. Adoption of improved crop management practices, 2002.

Improved crop management practices	MV adopters	
	No of households	% adoption
Improved nursery preparation	60	24.2
Improved land preparation	103	41.5
Use inorganic fertilizers	143	57.7
Change in planting time	38	15.3
Improved weed control methods	149	60.1
Improved pest control methods	41	16.5
Farm machinery use	92	37.1
Intensified land use (cropping system)	20	8.1

(Source: Impact assessment survey, 2002)

Note: Total numbers of respondents were 248 (from high altitude zones 105, medium altitude zone 83 and low altitude zone 60) for all crop management practices except for 'Intensified land use' in which only 78 responded from the medium altitude zone.

There is a higher percentage of adoption of improved management practices in the high altitude zone, followed by medium altitude zone (Figure 4). The data indicated that in the low altitude zone, the adoption of improved management practices such as application of inorganic fertilizers, improved weed management practices and mechanization are limited.

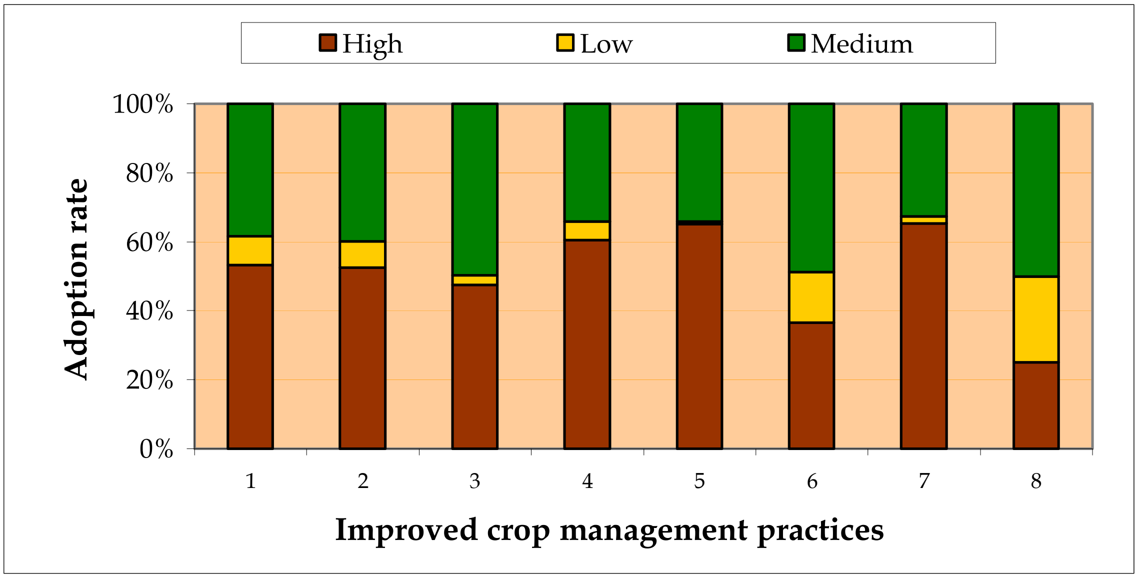

Figure 4. Adoption of improved crop management practices by altitude, 2002.

Note: Improved crop management practices are referred as follows:

1. Improved methods of nursery preparation
2. Improved methods of land preparation
3.Use inorganic fertilizers
4. Change planting time according to variety
5.Improved weed control methods
6.Improved pest control methods
7. Farm machinery use
8.Intensified land use (cropping system)

For these widely adopted improved management practices, the data were disaggregated to identify individual components (Table 15). Data from the households who have adopted the technologies are included in the analysis. Raised-seed bed preparation was adopted by 45% of the households. Among the land preparation methods, the use of power tillers for deep ploughing has spread widely (69%).

Table 15. Adoption of different components of improved crop management practices, 2002.

Improved crop management practices	MV adopters	
	No of households	% Adoption
Improved methods of nursery preparation		
Wet-bed nursery	17	28.3
Semi -dry nursery	16	26.7
Raised-bed seedling	27	45.0
Improved methods of land preparation		
Use power tiller	71	68.9
Plough land more than once	32	31.1
Use inorganic fertilizers		
Started application	117	81.8
Application as per recommendation	30	21.0
Improved weed control methods		
Herbicide applications	148	99.3
Intensive hand weeding	1	0.7
Farm machinery use		
Use mechanical harvester	39	42.4
Use mechanical thresher	53	57.6

(Source: Impact assessment survey, 2002)

Of the farmers who applied organic fertilizers, 21% of them reported to be applying at the recommended rate at transplanting, flowering and panicle initiation stage. Herbicide use was the most common method of controlling weeds. The common herbicide use is 'Butachlor' which gets rid of most weeds except for sochum. Farmers reported that when weeds are killed-off, it is easier to hand weed sochum. Machinery use is more common for harvesting (58%) than for threshing (42%).

The survey data indicated that farmers are using purchased inputs such as herbicides and fertilizers for both MV and TV rice varieties (Table 16). Input use in the high and medium altitude zones is higher compare to that in the low altitude zone.

Table 16. Fertilizers and herbicide use in different groups of rice varieties, 2002.

Inputs	High (kg/ha)		Medium (kg/ha)		Low (kg/ha)		All households (kg/ha)	
	TV	MV	TV	MV	TV	MV	TV	MV
Urea	102.4	96.3	127.2	136.6	7.0	12.2	78.9	81.7
Suphala	3.4	25.5	13.3	10.2	3.8	0.0	6.8	11.9
Herbicide	39.7	29.7	26.0	44.9	0.3	0.0	22.0	24.9

(Source: Impact assessment survey, 2002)

Generally, urea is applied as top dressing at transplanting. Overall, approximately, 80 kg/ha of urea is applied to TV and MV rice varieties. There is some variation in its applications level across different altitudes. The households in the medium and low altitude zones apply slightly higher levels of urea to MV. Twice as much of Suphala is applied to MV compare to TV, while there is little difference in application of herbicide between the two groups of rice varieties. The survey data indicated that there is almost no application of herbicide in the low altitude zone.

6.3.5. Increase in yield

The yield level of MV was higher compared to TV in all altitude zones (Table 17). The overall yield for MV is estimated at 3.62 t/ha and for TV at 2.84 t/ha. This represents a yield difference of MV over TV of 0.8 t/ha. The medium altitude zone attained the highest yield level for MV at 4.26 t/ha. The low altitude zone had the lowest yield for both groups of rice varieties. The yield advantage of MV over TV was 1.2 t/ha and 1.1 t/ha for the medium and low altitude zones, respectively. In the high altitude zone, the yield difference between the two groups of rice varieties was less than 2%.

Table 17. Weighted average yields for different groups of rice varieties, 2002.

Altitude	Yield (t/ha)		MV over TV	
	TV	MV	Difference (t/ha)	% Difference
High	3.21	3.26	0.05	1.5
Medium	3.08	4.26	1.18	38.2
Low	1.64	2.76	1.11	67.7
Overall	2.84	3.62	0.78	27.3

(Source: Impact assessment survey, 2002)

The BMV outperformed all other groups of MV rice varieties in all altitude zones (Figure 5, Appendix 17 for table). This indicates that BMV are more suited to all three environmental conditions relative to other released varieties. Overall, the yield level is estimated at 4.43 t/ha for BMV, 4.29 t/ha for IMV and 3.17 t/ha for OMV.

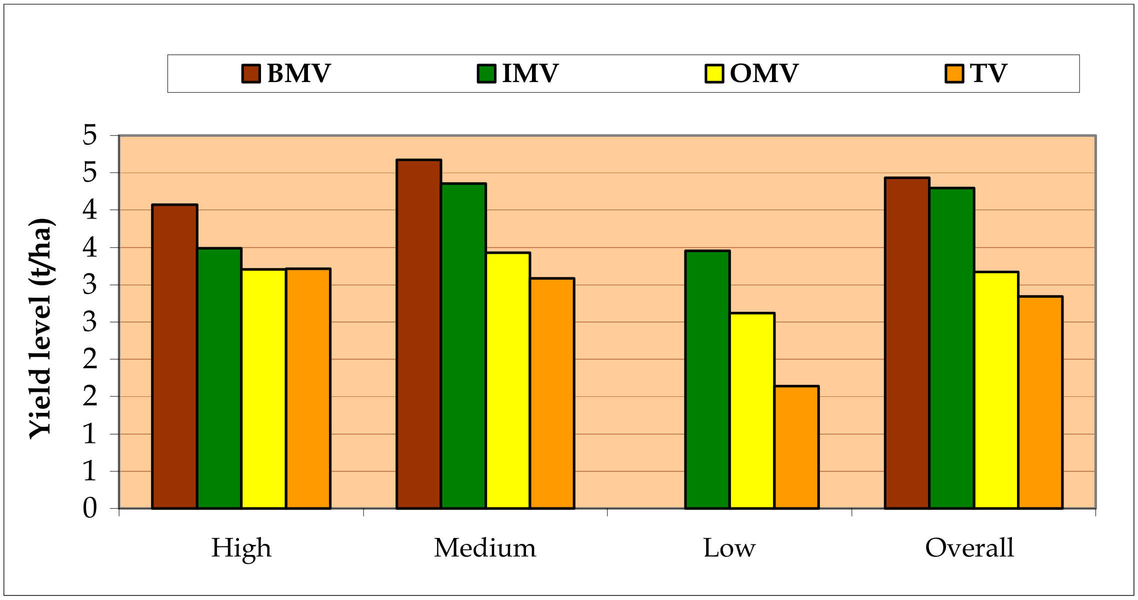

Figure 5. Weighted average yields for different rice varieties by altitude, 2002.

The yield level for each MV adopted is illustrated in Appendix 18. The highest yield level was recorded for MV variety, Bajo Kaap at 5.07 t/ha (BMV) and lowest yield for Khumal 2 at 1.90 t/ha (OMV). Both ranges were recorded in the Medium altitude.

In both the high and medium altitude zones, the difference between BMV over OMV was greater than for BMV over IMV (Table 18). In the overall estimation, BMV out-performed OMV by 40%, this represents a difference in yield of almost 1.3 t/ha. Of the two altitude zones, the gains of BMV over OMV are estimated to be higher in the medium altitude zone.

Table 18. Weighted average yields for different groups of MV, 2002.

Altitude[a]	Yield (t/ha)			Difference (t/ha)		% Difference	
	BMV	IMV	OMV	BMV over IMV	BMV over OMV	BMV over IMV	BMV over OMV
High	4.07	3.49	3.20	0.59	0.87	16.8	27.1
Medium	4.67	4.36	3.43	0.31	1.24	7.2	36.3
Overall	4.43	4.29	3.17	0.14	1.26	3.2	39.7

(Source: Impact assessment survey, 2002).

[a] BMV is not cultivated in the low altitude zone.

6.3.6. Increase in farmers' net incomes

The cost of production generally increases with the adoption of improved rice technologies. The additional expenses associated with the adoption of the new technologies are the additional cost of inorganic fertilizers, herbicides, farm machinery and labor. In calculating the net income, these additional costs need to be accounted for.

The survey data indicated that, farmers' cost of production increased for MV by approximately 200 Nu/ha (Table 19, see Appendix 19 for the detailed cost data). This represents an increase in cost by 17%. However, the net return increased by 28% resulting in an increase in farmers' net income by over 9,000 Nu/ha.

Table 19. Estimation of cost and net returns from different groups of rice varieties, 2002.

	TV	MV	MV over TV	
	Nu/ha	Nu/ha	Nu/ha	% Difference
Gross return	34,026	43,372	9,345	27.5
Paid out cost	1,142	1,339	197	17.2
Net return	32,884	42,033	9,148	27.8

(Data source: Impact assessment survey, 2002).

Note: The price of rice varies by region, color and other traits. The regional difference is the main factor influencing the retail price of rice (Planning Department 2002, see Appendix 20 for data). The farm survey data indicated that the MV-red rice commanded higher price compare to the MV-white in all altitude zones (Appendix 21). Although the price of MV was higher than TV, an average farm gate price of Nu 11,980 per ton is used to derive conservative estimated of net returns. Bhutan's currency is called Ngultrum (Nu), its current exchange is approximately US$1= Nu 44.

Net returns in the medium and low altitude zones are higher than in the high altitude zone (Table 20). The net returns are highest in the medium altitude zone at over 14,000 Nu/ha. The considerable difference in net returns among the three altitude zones is driven mainly by the yield difference. For example, the percentage difference in net returns among different altitude zones is similar to the percentage difference estimated for the yield level in Table 17. The low altitude has the highest percentage difference of over 65% for the net returns and yield level.

Table 20. Estimation of net returns by altitude, 2002.

Altitude	Net returns (Nu/ha)		MV over TV	
	TV	MV	Difference (Nu/ha)	% Difference
High	36,756	37,381	625	1.7
Medium	35,318	49,408	14,090	39.9
Low	19,555	32,289	12,734	65.1

(Data source: Impact assessment survey 2002).

6.3.7. Improvement in household rice self-sufficiency

Approximately, 68% of the sampled households have achieved self-sufficiency in rice (Table 21). The households in the high and medium altitude zones have higher rice self-sufficiency level at over 70% compared to the low altitude zone at 53%.

Table 21. Household rice self-sufficiency, 2002.

Altitude	Total sample households	% of household	
		Self-sufficient	Deficient
High	105	73.3	26.7
Medium	83	71.1	28.9
Low	60	53.3	46.7
Overall	248	67.7	32.3

(Source: Impact assessment survey, 2002).

Overall, 32% of the sampled households did not have self-sufficiency in rice. A disaggregated analysis was undertaken to examine the relationship between the level of self-sufficiency and the adoption of modern rice technologies.

In the medium altitude, the same level of deficiency in rice (50%) was reported by households adopting and non-adopting MV (Table 22). The households in the low altitude had substantially higher level of deficiency (79%) among the non-adopters. However, in the high altitude, MV adopters have higher percentage (68%) of food deficiency compare to the non-adopter (32%)[2]. Overall, MV adopters have a slightly higher level of rice self-sufficiency indicating a positive contribution of MV to household food security.

[2] This result for the high altitude zone may appear to be somewhat contrary to expectation. However, MV and TV have similar yields in the High altitude zones with MV being valued mainly for their blast rather than for yield advantage. Furthermore, households who grew MV had a smaller farm size but more people in the household relative to those who grew TV (Appendix 22).

Table 22. Households rice deficiency among adopter of MV, 2002.

Altitude	% of households deficiency	
	MV adopter	MV non-adopter
High	69.0	31.0
Medium	50.0	50.0
Low	21.4	78.6
Overall	46.9	53.1

(Source: Impact assessment survey, 2002).

6.3.9. Increase in household cash income from rice

Overall, MV adopter households have 110% more cash income from rice compared to the non-adopter households (Table 23). This represents a difference of approximately Nu 2,400 per household. The MV adopter households in the Medium altitude earn approximately Nu 4,000 more cash income. There is no significant difference (difference of less than Nu 200) in cash income in the high and low altitude zones among the two groups of households.

Table 23. Average household cash income from rice, 2002.

Altitude	Average household income		Adopter over non-adopter	
	MV adopter	Non-adopter	Difference (Nu)	% Difference
High	4,344	4,185	159	3.8
Medium	6,027	2,091	3,936	188.2
Low	925	1,122	(197)	-17.6
Overall	4,616	2,199	2,418	110.0

(Source: Impact assessment survey, 2002).

6.3.10. Improvement in general welfare

To get a general impression on changes in rural livelihoods, the households were asked whether they felt that their welfare had increased, decreased or remained constant during the last 5 to 8 years (Appendix 23). Different indicators of welfare were used for this analysis (Table 24).

Table 24. Households reporting increase in welfare in last 5 to 8 years, 2002.

Welfare indicators	% Households reporting increase
Self sufficiency in rice	67.2
Rice production	65.6
Overall income	78.8
House renovation	78.7
Children's health	95.8
Livestock number	24.8
Farm machinery	36.2
Farm knowledge	74.5

(Source: Impact assessment survey, 2002)

Based on these indicators most households reported that their welfare improved over time. Most significant improvement is reported for the children’s health (96%), overall income (79%), home estate (79%) and farm knowledge (75%). Over 66% of the surveyed households also stated that their rice production and self-sufficiency improved. More households reported to have increased ownership of farm machinery (36%) than livestock (25%).

The households who reported to have their welfare improved were categorized by adoption/non-adoption of MV to observe if there is any correlation. Consistently for all indicators, higher percentage (over 55%) of MV adopter reported to have improved their welfare compare to non-adopter (Figure 6). Rice production and its self-sufficiency among the MV adopters (70%) are significantly higher compared to non-adopters (30%).

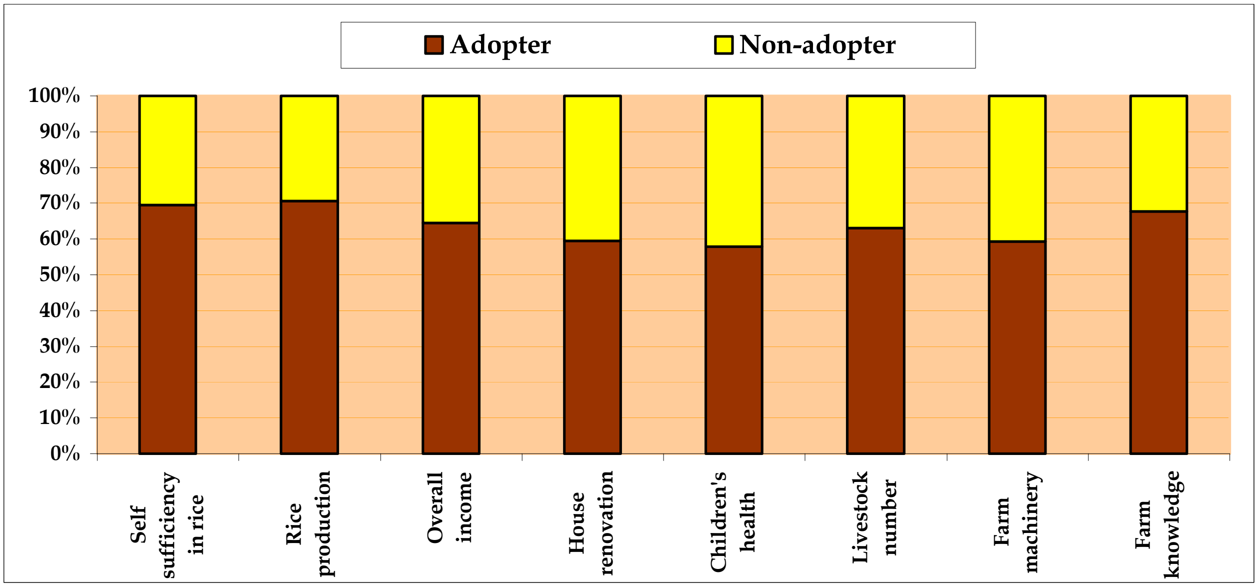

Figure 6. Improvement in welfare among MV adopter and non-adopter, 2002.

6.4. National level analysis

The results of above analysis at the farm level have been extrapolated to estimate the benefits attributable to improved rice technologies at the national level.

6.4.1. Increase in rice production

The magnitude of increase in production is dependent on rice area, MV adoption rate and yield difference between the two groups of rice varieties. For estimating the increase in rice production for the whole country, estimates of adoption rate of MV, and yield gain of MV over TV were derived from the farm survey data. It is assumed that MV adoption rate is 35%, the yield difference between MV and TV is 0.8 t/ha and the national estimated rice area of 26, 512.2 ha (Cadastral survey). Using these estimates, the increase in national rice production attributable to improved rice technologies is estimated at over 6800 t in 2002 (Table 25). At the farm gate price of Nu 11,980 per ton, the value of increased production is estimated to be approximately, Nu 82 million per year.

Table 25. Estimation of increase in rice production at the national level.

Altitude	National rice area (ha)	Area affected by MV adoption (ha)	Increase in production (t)	% Contribution by altitude
High	5,302	3,510	173	2.5
Medium	10,605	3,972	4,681	68.6
Low	10,605	1,771	1,970	28.9
National	26,512	9,252	6,824	100

(Data source: Impact assessment survey, 2002).

Note: Increase in national production is derived by multiplying percentage of MV adoption rate, yield difference of MV over TV and total rice area. Yield difference from Table 17, MV adoption rate presented in Table 12, and Cadastral survey's estimations of national rice area were used in deriving the total increase in rice production (refer to Appendix 24 for detail calculations).

Approximately, 69% of the increased production originated from the medium altitude zone, and nearly 29% from the low altitude. Despite the highest MV adoption rate in the high altitude zone (66%), its contribution to the increased national production is minimal (less than 3%). This is due mainly to the small difference in productivity between the two groups of varieties and a relatively smaller rice area in the high altitude.

The estimation in Table 26 illustrates the relative share of different MV groups in rice production gain. When disaggregated by variety categories, IMV contributed nearly 57% of the estimated 6800 t increase in the national production. Most of this originated from the adoption of IMV in the medium altitude zone. The OMV and BMV contributed approximately 27% and 16%, respectively. The gains from BMV were lowest due mainly to the currently low rate of adoption of BMV at the national level (see Section 6.5.3. for estimated gains based on higher BMV adoption rate).

Table 26. Estimation of increase in rice production from different groups of MV.

Different groups of MV	Rice production (t)				% Contribution by different groups of MV
	High	Medium	Low	National	
BMV	154	966	*	1,120	16.4
IMV	12	3,561	300	3,873	56.8
OMV	7	154	1,670	1,831	26.8
Total MV	173	4,681	1,970	6,824	100

(Data source: Impact assessment survey, 2002)
* not applicable

6.4.2. Increase in net returns

The per hectare gain in net returns of Nu 9,000 translates to a gain of over Nu 80 million at the national level (Table 27). Approximately, 70% of the total net returns originated from the medium altitude zone.

Table 27. Estimation of net returns at the national level.

Altitude	Net returns ('000 Nu)	Contribution by altitude (%)
High	2,195	2.7
Medium	55,967	69.3
Low	22,549	27.9
National	80,711	100

(Source: Impact assessment survey 2002).

Note: Net returns at the national level is derived by multiplying per hectare difference in net returns of MV over TV and the area affected by the adoption of MV (see Appendix 24 for detail calculations).

There is relatively little difference in the cost of production of MV and TV, hence, the net returns at the national level are close to the value of gain in gross production. Alternative estimations of net returns assuming substantially increased cost of production for MV compare to the TV are presented in later part of the report (see Section 6.5.4.).

6.5. Sensitivity analysis of benefit estimates

6.5.1. Production and net returns for different data sources

Sensitivity analysis was conducted to estimate a range of benefits using different sources of data. The estimated value of increase in national rice production and net returns attributable to new rice technologies when different data sources are used is illustrated in Table 28.

Table 28. Estimation of increases in rice production and net returns for different data sources.

Different data sources	Rice area (ha)	Area adopted to MV[a]	Gain in rice production (t)	Value of production gained ('000 Nu)[b]	Net returns (Nu '000)
RNR statistics	19,395	6,769	4,992	59,814	58,341
Cadastral survey	26,512	9,252	6,824	81,762	79,748
GIS/LUPP	39,240	13,694	10,100	121,013	118,032
FAO	30,000	10,470	7,722	92,518	90,239
Average	28,787	10,046	7,410	88,777	86,590

(Data source: Impact assessment survey, 2002).

[a] Estimated based on 35% MV adoption at the national level.

[b] The gains in rice production is valued at the farm-gate price of Nu. 11,980 per ton (paddy price).

The estimated increase in rice production ranged from 5,000 t to 10,000 t for different data sources, its value at the farm-gate price is Nu 59 million to Nu 121 million, respectively. The estimated net returns ranges from over Nu 58 million to Nu 118 million. The estimated benefits, increase in production and net returns, for GIS/LUPP is almost twice the level estimated based on RNR statistics.

6.5.2. Adoption of different rates of modern rice varieties

There have not been any other studies for determining the MV adoption rate at the national level. The present study collected data covering all three rice altitude zones from seven dzongkhags from across the country. The MV adoption rate of 35% at the national level was derived by assigning weights to different altitude zones according to their percentage area of the total rice area. To allow for the possible inaccuracies in the sample data the MV adoption rates of 25% and

50% were used to re-estimate the benefits (Table 29). For a conservative MV adoption rate of 25%, Bhutan would still gain in rice production by over 5,000 (t) a year and net returns of almost Nu 60 millions a year.

Table 29. Production and net returns for different rates of MV adoption.

MV adoption rate (%)	Area adopted to MV (ha)	Increased production (t)	Net returns ('000 Nu)
25	6,628	5,141	60,294
30	7,954	6,170	72,353
35	9,252	6,824	80,711
40	10,605	8,226	96,471
45	11,931	9,254	108,530
50	13,256	10,283	120,589

(Data source: Impact assessment survey 2002).

6.5.3. Adoption of different rates of Bhutanese rice varieties

The IMV and OMV are varieties that been bred elsewhere and introduced in Bhutan through the varietal introduction program (see Section 3.1.1.). Hence, it could be argued that even without RNR-RC, the country would have adopted such MV over time and benefited from it. In this scenario, there would have been no gain in yield from the adoption of OMV and IMV as these varieties would have been grown even without RNR-RCs efforts. BMV would represent the main output of research conducted in Bhutan under this scenario. The benefit from BMV is estimated under the assumption that either OMV or IMV would have been grown had BMV not been available. Under this scenario, the benefit attributable to RNR-RC's cross breeding program (see Section 3.1.2.) is estimated at 1,100 t per year (Table 30).

Table 30. Increase in rice production attributable to adoption of BMV.

Increase in production (t)	Rice production (t)			% Contribution by different groups of MV
	High	Medium	National	
BMV over IMV	57.7	197.9	255.6	22.8
BMV over OMV	84.8	781.9	866.7	77.2
Overall	142.5	979.8	1,122.4	100

(Data source: Impact assessment survey 2002).

6.5.4. Net returns for different rates of production cost

The earlier estimates of gain in net returns derived under the assumption that the cost of inputs increased by 17%. How sensitive the results would be under the extreme assumption that the cost increased by 100% or more? The estimated net returns for increase in cost from the current rate of 17% to 200% is illustrated in Figure 8, (see Appendix 26 for table). If we assume that the cost of production increases by 100%, the estimated net returns under this assumption is 8,200 Nu/ha. At the national level, this translates to a gain of almost Nu. 76 million. Even with such level of increase in cost, the benefits reduced by 12% only. This indicates that the results are not very sensitive to assumptions about the increase in cost of inputs.

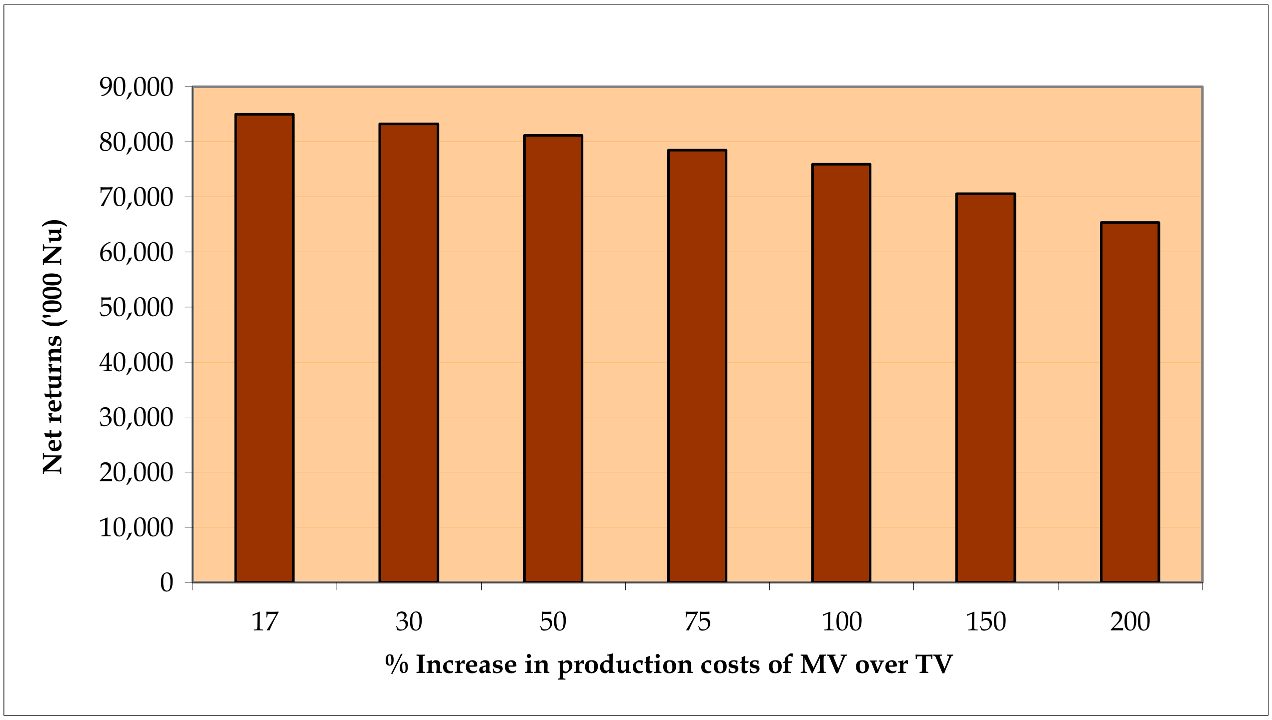

Figure 8. Changes in net income for different production costs.

6.6. Impact of institutional capacity building

The establishment of RNR-RCs has been the principle source of capacity building in agricultural research for the country. Its capacity to plan, undertake and implement agriculture research was the direct result of the efforts made at human capacity developments. The types and the timing of the trainings undertaken are viewed as essential in supporting the institute that has expanded from one to four separate research centers. The food crops research that had less than 10 qualified staff has expanded to include current staff of over 30 with university degrees in diverse disciplines ranging from biological, agronomical, engineering and social sciences.

6.6.1. Training

The IRRI and other institutes, mostly from SAARC countries, have been the main providers of training to Bhutanese (Table 31). A total of 182 capacity building opportunities (training, seminar and conference participations etc.) in agricultural research and management have been made available so far. Almost a half of the training activities were conducted at IRRI and included mainly non-degree training on specific topics. Two staff completed M.Sc. with supervisions from IRRI's senior staff. These training activities were focused mainly on rice during the early stages of the institute.

Table 31. Number of agricultural research capacity building opportunities, 1983-2002.

Course category	Training at IRRI	Opportunities at other institutes[b]		Percentage of total
		Non-degree training	Study tours/ conference/ seminars	
Varietal improvement	6	4	7	9.3
Crop management				
Nutrient	9	2	3	7.7
Pest	6		1	3.8
Water	10	5	4	10.4
Agricultural engineering	7			3.8
Rice production technology	9	2		6.0
Research management and leadership	3	2	27	17.6
Technology transfer	20	1	1	12.1
Others				
Social sciences	1			0.5
Cropping systems	2	3	19	13.2
Technical training	1	5	2	4.4
NRM	0	1	1	1.1
On-the-job training	16			8.8
Total	92	25	65	100.0

(Source: IRRI alumni database 2002, and RNR-RCs annual reports 1993-2002).

[a.] In addition to these capacity buildings, there were also six degree trainings (four M.Sc. and two Diplomas). [b]The RNR-RCs capacity building opportunities (training, workshop, seminars and conference etc.) is compiled from RNR-RCs annual reports. All opportunities from RNR- RC Bajo and training on food crops from other RCs are listed.

The nature of the training activities evolved with the expansion of the mandate and increasing demand for other aspects of research and management. The institute also invested in training on research management and technical training on computer and other skills needed to support the growing centers. Training programs included problem-oriented, multidisciplinary and integrative research on various aspects of farming systems. The themes included cropping systems, socio-economic analysis, and gender studies. Rather than relying on one or two centers of excellence, training is increasingly obtained from multiple suppliers including the neighboring countries. This has encouraged a healthy cross-fertilization of ideas and perspectives among the staff. Overall, these training programs served the key role in building the critical mass of skilled staff within a relatively short period of time.

Some 18% of the training activities were targeted to building research management and leadership skills. Some of the trainees are now in the leadership position at RNR-RCs. The institute's development during last two decades can be traced to improved research and management capacity of its staff.

6.6.2. Research program

The germplams improvement program has progressed from evaluation of elite lines from outside sources to cross breeding with local parents. Under the cross breeding program, scientists in Bhutan take the leadership in the collection, evaluation and identification of parent materials. There are then sent to IRRI for actual crossing only. Progenies from crosses are sent back to Bhutan for various stages of evaluations and final introduction to the country. Most of the varieties released nationally during the past five years originated from these cross breeding programs. Improved varieties of rice for high altitude zone with tolerant to cold temperature have been developed for the rice agro-ecologies that is considered to be the most challenging for rice breeders.

With improved capacity, the research focus has become much more integrative of different aspects of rice technologies both during the experimental stage and field-testing. New varieties are often evaluated in combination with alternative treatments for nutrient management that also include rotational cropping. The research program has also expanded to include broader issues such as conservation of biodiversity and natural resources. Overall, the research approach has matured considerably from being narrowly focused in one or two disciplines in the early years to being truly multidisciplinary and systems-oriented.

6.6.3. Research planning, management and implementation

Planning, management and implementation of research programs have improved considerably and become stronger over time. The programs are lead by strong and capable leaders with the foresight that are based on the real needs of the country. The Program Directors' (Center heads) trainings match the center's national mandates well and the Directors are often directly involved in research. This direct involvement has helped them to obtain first hand knowledge of the opportunities and constraints of the center and their staff.

The infrastructure and research facilities have also improved over time. These infrastructures include new office complexes and research equipments. Almost all research staff have individual computers and RNR-RCs are one of the first governments institutes to have full access to internet facilities.

Several mechanisms are also in place to have the four centers work more effectively in pursuit of their national and regional mandates. There are regular joint trainings and workshops opportunities for the staff from different centers to work and learn from one another. The bi-annual workshops among the center heads and key staff have contributed to developing more integrative research programs. Regular workshops are also organized with extensions departments to facilitate in information sharing.

6.6.4. Improved national, regional and international collaborations

The RNR-RC Bajo has evolved to become a major player in important aspects of agricultural planning and development in the country. The center is consulted and advice sought by government departments. They are often given the lead roles in national-level planning and policy-making in agricultural sector. The centers have developed strong collaborative networks with various government agencies. There is a regular exchange of visits among research and support staff of various institutes.

The centers have also started to take lead roles in initiating collaboration with donors and international institutes as well as in managing the international relations. The donor community and international research and development institutes are seen as fundamental to establishing research systems and keeping the information flow. The research centers are now taking the lead role in planning and managing the Bhutan-IDRC-IRRI collaboration. This collaboration has expanded now and is co-funded by IDRC and SDC. The RCs are also able to promote themselves to new donors and UN agencies such as IFAD and FAO, who are now contributing loans and grants to support agricultural research and development.

Strong linkages have also been developed with other the consultative Group on International Agricultural Research (CGIAR) institutions such as the Asian Vegetable Research and Development Center (AVRDC), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the International Service for National Agricultural Research (ISNAR), and the International Center for Integrated Mountains (ICIMOD). Recently, a Memorandum of Understanding (MOU) has also been signed with the International Food Policy Research Institute (IFPRI) and IPGRI. Strong collaborations have been established with the agricultural research systems of several Asian countries such as India, Nepal, Bangladesh, Sri Lanka, Taiwan, Japan, Korea and Thailand.

8. Subjective assessment of the research and capacity building program

A subjective assessment based on interviews with some major stakeholders was conducted to complement the quantitative analysis presented above. High-level government officials, key research staff, international partners and extension personnel were interviewed to elicit their broader impressions of the impact of the overall program (list of people interviewed in Appendix 5). During the interviews, they were also requested to provide comments/suggestions regarding program balance and strategies so that future impact could be further increased.

The responses obtained grouped by major themes are summarized in Table 32. Subjective assessment of the general magnitude of impact for different component of research and technology development program is ranked at four levels. The symbols represent as follows:

**** Excellent impact, consistently performed well.

*** Good impact, could improve substantially with some changes.

** Positive impact, prioritizing and reorganizing could further improve the impact.

* Recently undertaken efforts or those that may need to make major changes to generate the desired impact.

Over 90% of the people interviewed considered improved rice technologies as the main source of increased production. The varietal improvement component was considered to have had the most impact. The contribution of varietal improvement to production gain was estimated to be in the range of 25 to 80%, with most of the estimates centered around 50%. Improved nutrient and weed management practices were mention as other factors that were important in contributing to the increased production. The research on weed management practices, in particular to sochum, was highly regarded. The release of blast resistance variety was considered to have significantly contributed to preventing yield-loss from the blast prone high altitude zone.

Table 32. Subjective assessment of the rice research and capacity building program, 2002.

Rice research program	Magnitude of impact	Comments/suggestions/ concerns
1. Research		
(a). Improved varieties	****	• Effective in selection and breeding of locally adapted varieties that are high-yielding, have disease resistance with locally preferred quality traits for the challenging and highly variable ecosystems. • The post-harvest concerns such as ease of threshing and non-shattering traits have also been incorporated in developing newer improved varieties. • Need to develop BMV for the low altitude zone.
(b). Crop management practices	***	• Research on integrated nutrient management that includes a balanced use of organic and inorganic

		sources is in line with the broader national objective of conservation farming. • Inorganic fertilizer recommendations are developed to suit different categories of farmers. • Environmentally and socially responsible attitude towards not using pesticide to eradicate rice insects and diseases developed. • Rice breeders have done well to develop ranges of improved agronomic practices despite the shortage of qualified agronomists in recent years. • Need to develop improved agronomic practices that reduces labor requirement • Wide use of Butachlor to get-ride of other weeds may be promoting the sochum growth. • Rice research program is heavily tilted towards breeding of improved varieties and not enough efforts placed in the development of other rice technologies. • Studies need to be strengthened to reduce post-harvest losses, improve red-rice milling recovery and improve grain quality.
(c). Cropping systems	***	• Changes in the traditional rice-fallow cropping pattern towards more intensive and diversified cropping pattern are due to cropping systems research and introduction of new and wider varieties of vegetables and other cereal crops. • Effective strategies (and research) needs to be developed that does not put pressure on labor at peak seasons to further expand multiple cropping.

3. Technology transfer	**	• In addition to information leaflets, efforts are needed for more effective and comprehensive dissemination process. • Extension agents need to improve knowledge in technical aspects of their area of responsibility. • Rewards systems need to be institutionalized for better integration of research with district level extension officers who are mainly in the frontline of technology dissemination process. • Extension groups appreciate the research staff involvement for regular problem diagnosis. However, the research groups would prefer that they be called on only for the complex and unusual problem situations as these visits are time consuming taking away time from research. • During annual meeting between research and extension management teams extension staff need to specify and prioritize problem areas that require research interventions.
(a). Research capacity	***	• Accelerated the development of research capacity within two decades. The staff performance is above average and the recent hiring of staff with specialized skills is expected to further improve the impact. • Research center staff are some of the best-qualified ones in the country. The food crops program is managed and led by the country's most qualified personnel in their area of expertise. • Capacity building needs to focus on opportunities closer to Bhutan which have training activities more relevant to the local conditions, and can be achieved much more cost efficiently.

(b). Research planning, management and implementation	***	• Research programs are consistent with the national food policies and the goals of the other sectors. • The research groups provide critical inputs to planning and policy designs at the national levels. • The plans and policy design are implemented with speed and efficiency. For example, once the biodiversity was recognized as a priority issue, research capacity in the area was quickly built-up, and steps were taken to safeguard the diversity of rice genepool. • There is a general camaraderie and high-level of understanding between the management and the staff. • Research performance could be improved further if the centers are consulted in staff allocations and transfers. • The food crops research program need to have a balanced research focus on other major cereal crops such as wheat, maize etc. • Production constraints in the low altitude zone, which accounts for 40% of the rice area, have not been adequately addressed in research programs.
(c). Collaborations	****	• Effective in development and management of the linkages with international and regional centers outside Bhutan. • The international staff indicated that Bhutanese scientists collaborating with them are hardworking and committed. • Collaborative activities with international partners involving exchange of materials and information have been mutually beneficial. • RNR-RC Bajo is supportive and works effectively with other government agencies working on programs of common interest.

(d). Publications	*	• Need to institutionalize the reward systems to improve the scientific exchange and reporting at RCs, nationally and internationally. • Some form of media outlet needs to be established to disseminate and update research finding on a regular basis.

(Source: Impact assessment survey, 2002)

8. Conclusions and recommendations

The rice research program of Bhutan has generated substantial impact as documented in this report. Fifteen modern varieties have been officially released and a suite of complementary crop management technologies has been developed. The MV have yield advantage of more than 27% over TV. The BMV, a group of MV crossbred specifically for Bhutan, outperformed all other groups of MV. Under the farmer management, the BMV yielded 40% more than the OMV. The increase in rice production from the new rice technologies was estimated to be in the range of 5,000 t to 10,000 t per year for the country as a whole. This is equivalent to a gain in net returns between Nu 58 million and Nu 181 million per year. The improved rice technologies have contributed to improvements in the household and the national level rice self-sufficiency. As rice production is one of the main activities in the rural economy, increases in its productivity have also generated positive impacts by facilitating crop diversification and cash cropping.

The rice research program has also generated a major impact in terms of capacity building. A substantial pool of scientific skills has been developed through over 180 training and other skill building opportunities. Within a relatively short period, the centers have been able to develop a critical number of staff possessing both technical and management skills. This cadre of staff is now contributing to the overall development of agriculture through greater ability to plan, prioritize, and implement research and technology development. In addition, research infrastructures needed for efficient functioning of a research system have been established.

The benefit of the new rice technologies is apparent in all rice altitude zones. However, the extent of benefit varies greatly across the three different altitude zones. Most of the research efforts were placed in generating technologies for the medium altitude and thereby the households in this altitude benefited the most. By comparison, the data indicated that the low altitude zones did not fare as well.

Reinforcement of the impact documented here will require multiple interventions that encompass agricultural research, extension, and policy support for agricultural development. Clearly, a discussion of the design of such wide-ranging interventions is beyond the scope of this study. Nevertheless, the following suggestions specifically related to rice research and technology development are made on the basis of the findings of this study.

- Despite having 40% share in rice area, the low altitude zone has contributed to only 29% of the increase in production. The relatively smaller contribution of the low altitude zone is due to low yield and low adoption of MV (only 17% of the rice area) in this zone. With suitable technologies, the region can contribute substantially to the national food supply and help reduce dependence on imports. For example, the national output of rice could increase by additional 5000 t (or by 8%) assuming that the area under the currently-grown modern varieties expands to 60% of the rice area. If the yield of MV could also be raised simultaneously, this contribution will further increase. Marginal returns to additional investments in rice research targeted to this region are, hence, likely to be substantial. A thorough analysis of the desirability of reallocating additional research resources to this region is suggested.

- Research and extension both have critical roles to play in generating the desired impact. Over the years, the extension agents have performed an important role in taking information about new technologies and other opportunities to remote parts of the country. Given the important role of extension in bridging the two-way flow of information between farmers and researchers, further strengthening of skills and capacity of the extension system seem desirable.

- The positive impact documented here resulted mainly from the adoption of improved varieties. While some complementary crop management technologies are available, there is a need to more effectively integrate the various components of rice technologies in the form of "basket of options" suitable to different agro-ecological and socio-economic domains.

- Rice yield in Bhutan is limited by a number of biotic and abiotic stresses. Research resources are currently being allocated to addressing these constraints. Socio-economic analyses to serve as a basis for prioritizing these constraints for a more efficient allocation of limited research resources seem desirable.

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Appendix 1.Households with food grain shortages and coping mechanisms.

Dzongkhag[1] (Districts)/ Altitude	Househeolds with food grain shortage (%)	Food grain shortage (months)	Food grain shortage and coping mechanisms by households (%)					
			Purchase			Borrow from neighbour	Barter with livestock products	Exchange with labour
			FCB	Market	Neighbour			
High								
Bumthang	67.9	2.7	60.8	85.2	6.2	19.2	10.5	18.5
Gasa	74.2	6.4	84.2	81	4.3	9.2	56.5	37
Haa	73.7	2.7	85.2	59.3	11.7	19.4	13	18.3
Paro	59.8	2.7	87.6	86.2	9.4	17.6	11.4	25
Thimphu	58.9	2.9	84.8	84.9	6.4	16.5	11.4	27.7
Medium								
Chhukha	79.9	3.1	71.5	81.6	12.4	25.5	9.8	33
Dagana	63	2.5	55.8	95.4	13.9	17.2	4.4	27.1
Lhuentse	41.7	1	67	52.1	19	47.5	5.4	14.1
Mongar	33.8	0.8	63.7	54.8	31	53.5	4.3	40.5
Pemagatshel	58.1	1.8	80.3	76.4	15.6	38.5	2.5	27.4
Punakha	47.3	1.5	72.8	52	14.5	37.7	8.6	26.3
Trashigang	44	1.3	78.4	66.1	21.2	40.5	14.8	31.1
Trongsa	59.4	1.6	73	79	7.5	24.2	9.1	23.2
Tsirang	71.1	3.2	61.9	93.3	12.7	14.5	5	29.1
Wangdue	55.4	1.7	64.7	57.3	14	28.4	19.1	24
Yangtse	43	1.2	66.3	64.4	22	44	5.7	24.6
Zhemgang	56.4	1.5	85.1	77.8	13.8	26.8	11.5	19.8
Low								
Samtse	84.8	2.9	28.7	97.9	15.4	27.1	6.3	28.4
Sarpang	61.8	2.7	66.4	94.7	12.8	15.9	3.9	20.1
S/Jongkhar	43.6	1.1	44.8	74.7	21.6	48.4	1.9	39.9
National	**56.1**	**2.2**	**65.9**	**72.1**	**13.6**	**27.2**	**10.2**	**25.5**

(Source: RNR Statistics 2002, eletronic database)

Note: The rice growing environment is divided into three distinct zones and associated with particular dzongkhags. However, a dzongkhag could contain one or more rice altitude zones. The categorization of dzongkhags to different altitude zones is based on Eighth Five Year Plan for commodity program.

Appendix 2. Survey Questionnaire.

Renewable Natural Resources Research Centers, Bhutan

Impact assessment of agricultural technologies

Field survey questionnaire

Farmer name ___________________________

Farmer code___________________________

Dzongkhag _____________________________

Altitude_________________________________

Geog and Village name__________________

Interview date ___________________________

Enumerator ____________________________

A. General Information

1.Demographic information of the farmer interviewed

Information about interviewee (Head of the household)				Numbers of Household Members			
Age	Sex	Education[1] (Years in school)	Occupation (Primary)	Male (15 and older)	Female (15 and older)	Children	Total

2. Agricultural land holding and land use

Parcel no.	Parcel name	Wet or Dry land	Parcel area (ld.)	Land ownership	Land quality	**Summer crop (July-Oct/Nov, 2002)**		**Second crop (March -June/July 2002)**	
						Rice (Area, ld.)	Name other crop	Rice (Area, ld.)	Name other crop

Land area
Wet land (irrigated) 1 langdo (ld) = .25 acres
Dry land (non-irrigated) 1 langdo (ld.) = .33 acres

Land ownership
Own = 1
Share-in= 2
Share-Out =3

Land quality
Raap =1
Dring =2
Tha =3

B. Adoption of agricultural technologies

3 (a). <u>Rice</u> varieties planted in Summer (June-Oct/Nov, 2002)

Name of rice variety		Area under the variety (ld)	Production (dre.)	Year first planted	Reason for planting the variety	Original seed source	TV/MV
Parcel No.	Variety name						

3 (b). <u>Rice</u> varieties planted in <u>Second crop (March-June/July 2001-2)</u>

Name of rice variety		Area under the variety**?** (ld.)	Production (dre.)	Year first planted	Reason for planting the variety	Original seed source	TV/M V
Parcel No.	Variety name						

RNR-RCs MVs:

IR 64,	*Bajo Maap 1 and 2*
IR 20913	*Bajo Kaap 1 and 2*
No. 11	*Khangma Maap*
Khumal 2	*Khangma Maap*
Barket	*Yusi Ray Maap*
Milyang 54	*Yusi Ray Kaap*

Other MVs

MVs 1?
MVs 2?

<u>1 dre.= 1.24 kg. for Rice</u>

Some popular TVs are:

Zakha
Tan Tshenring
Local Maap
Local Kaap

4. Adoption of other Rice Technologies

Over the last 5-8 years, what other major changes in rice production have you adopted?

Activity	Nature of change	Year adopted	% of rice area adopted?	Reason(s) for	
				Adopting	Not adopting
Seedling production[1]					
Land preparation[2]					
Time of Planting[3]					
Plant spacing [4]					
Chemical Fertilizer Application [5]					
Pest control[6]					
Weed Control[7]					
Harvesting/threshing[8]					
Cropping systems[9]					
Others					

Some of the changes in rice technologies could be as follow:

[1]*shorter seed-bed preparation e.g. semi-dry, wet-bed methods*

[2] *Machine use in land preparation, number of times you plough the land before planting rice, 2/3?*

[3] *Change in timing of transplantation for MVs , e.g. 6/7 Bhutanese month*

[4] *Adoption of new plant spacing e.g. 20 x 20 cm, other agronomic changes*

[5] *Start in application of chemical fertilizer, application at transplanting and/or at flowering stage, Spot application of chemical fertilizer*

[6] *Spot application as insects are seen, identification of rice insects and diseases etc.*

[7] *Use of herbicide before transplanting rice, application of herbicide within 3-6 days of transplanting rice, hand pulling shochum weed*

[8]*Adoption of machinery for threshing and harvesting, identify method used e.g. power thresher*

[9]*Start of double rice cropping, planting a second crop following rice etc.*

5. <u>Other crops</u> planted in Winter

Name of the crop	TV/ MV	Total area (Ld.)	Total production (dre.)	Year first planted	Reason for planting the variety	Original seed source
Wheat						
Maize						
Mustard						
Buckwheat						
Barley						
Other (crop name)						
Fallow						

---

1 dre. = 1.56 kg. Wheat

1 dre. = 1.42 kg. Mustard

1dre. = kg. Maize

1 dre = kg. Buckwheat

C. **Input Use**

6. Inputs used in rice production

Input Usage (Unit as appropriate)	Modern Varieties (Summer)			Modern Variety (Second crop)			Traditional Varieties (Usually in Summer)		
	Total Area (Ld.)	Total quantity	Unit price (Nu)	Total Area (Ld.)	Total quantity	Unit price (Nu.)	Total Area (Ld.)	Total Quantity	Unit price (Nu)
Inorganic fertilizer 1. Urea[2] (Per bag)									
2. Suphala[2] (Per bag)									
Herbicide[3] (Per bag)									
Pesticide[3] (Per bottle)									
Farm machinery (**hire and fuel cost**)									
Seed cost									
Other expenses									

[2] *1 Bag of Urea, Suphala = kg.*

[3] *1 Bag or bottle of Pesticide/Herbicide/Insecticide = kg or ltr*

D. Agricultural Production, Income Sources and General Conditions

7 (a). <u>Questions for Rice Surplus Farmers Only</u>

Rice variety/Rice product	Production (dre.)	Sale[1]			Payment /loan (dre.)	Milled rice requirement for the year (dre.)	Stored for seed (dre.)
		Quantity (dre.)	Price (Nu/dre.)	Value (Nu.)			
1.							
2.							
3.							
Total							

7 (b). <u>Questions for Rice Deficit Farmers Only</u>

For how many month(s) did you **<u>not</u>** have rice? _________________please indicate the month.

Total Production (dre.)	Purchased			Borrowed (dre.)	What other crop do you substitute for rice?
	Quantity (dre.)	Price (Nu/dre.)	Value (Nu)		

[1]*Please specify, Rice, Milled rice, Zaow, Sip etc. any rice products sold*

8. Annual household cash income

Sources	Value of the total products sold for the Agricultural year
Rice and rice products[1]	
Other crops[1] (Wheat, mustard, maize etc)	
Vegetables and Fruits[1] (Chili, tomatoes, apples etc.)	
Livestock production[1] (Milk, butter, cheese, animals etc.)	
Off-farm employment[2] (Hired labor farm work)	
Non-farm employment[2] (Work at town, service holder, road construction)	
Remittance[2]	
Non-timber forest products	
Others (specify)	

[1] *Products sold*
[2] *If paid monthly or yearly, please record and indicate.*

Off-farm employment*: Refers to paid activities related to agricultural work in others' farm e. g. hired labor to care for animal, land preparation etc.*

Non-farm employment: *Refers to paid activities outside the farming sector e.g. road construction, transportation services, tourism industry etc.*

9. Over the past 5-8 years what changes have occurred in your household?

Factors	Increased	Decreased	Constant	Briefly discuss why and how these changes occurred
Rice production				
Self-sufficiency in rice				
Overall income				
Home improvement				
Pilgrimage				
Children's health				
Livestock numbers				
Farm machinery ownership				
New knowledge of Farming practices				
Others				

E. Access to Farming Information

10. Where do you get most of your information on agricultural production systems?

Factors	Own experience	Relatives/ neighbors	Extension officers	Demonstration trials/field day/training	Radio/TVs/ newspaper	Others (Name)
Agricultural production						
New varieties						
Land preparation						
Chemical fertilize						
MVs planting time						
Rice pest control						
Weed control						
Farm machinery						
Marketing information						
Others						

Some of the sources of information could be:

Own experience
Other family members
Neighbors/ other farmers
RNR-RCs thru demonstration trials, exhibitions and trainings
Other NGO/ extension workers
Radio/television/newspaper/other media
Others (specify)

Appendix 2. Rice area, production and other statistics for surveyed Dzongkhags.

Dzongkhag (District)	Area (ha)	Production (t)	Yield (t/ha)	Rice sold % of Total	Food grain shortage % of HH	Food grain shortage Months
Paro	1,269	3,083	2.43	2.7	59.8	2.7
Thimphu	690	2,151	3.11	2.3	58.9	2.9
Punakha	1,971	6,274	3.18	2.5	47.3	1.5
Trashigang	941	2,440	2.59	1.8	44.0	1.3
Wangdue	1,467	4,024	2.74	1.6	55.4	1.7
Samtse	2,889	4,650	1.61	0.2	84.8	2.9
Sarpang	2,839	5,830	2.05	0.6	61.8	2.7
For National[a]	**19,395**	**44,298**	**2.28**	**1.2**	**56.1**	**1.7**

(Source: MAO 2001).

[a] These seven dzongkhags make up 62% and 64% national area and production, respectively.

Appendix 4. Name of dzongkhags, goegs and villages included in the imapct assessment survey, 2002.

Dzongkhags (districts)	Geogs (Blocks)	Name of the villages
Paro	Doga	Chubar, Dhushar, Lechu, Luthroe, Jabjay and Pusha.
	Shapa	Ddingkha
	Wangchang	Changkar
	Dopshari	Jangsa, Ramna, Ruchukha, and Shari
	Lungnyi	Bondey, Lungnyi, Jewphu, Gebjana, Getana, Woochu and Zdakha
Punakha	Kabji	Wokuna and Sirigang.
	Chubu	Gangkhalo and Jawakha.
	Zomi	Gubji and Khawazara.
Samtse	Chengmari	Bimtar, Garigmo, Katari, Kothari, and Masey.
	Samste	Buduney, Chalikoop and Manchetar.
	Biru	Birutar, khotitar and Lamatar.
	Nainital	Botey, Bhaungaon, Bitchgoan, Bowngoan, Raigaon, Newargaon and Thakurigaon.
Sarpang	Chusegang Umling Gaylephug Sarpangtar	Village names not listed in the worksheets.
Thimphu	Mewang	Kdrapchu, Sigay, and Tsaphu.
	Genye	Bama, Bechumo, Cthanka, Dupgi, Gacarmo, Ggokha and Yangoe.
Trashigang	Radi	Chena, Dekling, Langtal, Pangthang, Radhi, Radi Pangthang, Pakaling, Tanglamani, Tshatsi and Zonla
	Phongme	Bumtang, Gazeray, Lakhang, Lemp, Monangkhar and Tongleng.
	Bartsham	Braimang, Jongdung, Hingong Ugdama, Manchang, Muktangkhar, Sekhar, Yangkhar and Zongthang.
	Shongphu	Changme, Khaling and Shongphu.
Wangdue	Nisho	Chebakha and Lakhokha.
	Tetsho	Bajothang, Thangu and Rinchengang.
	Gasewom	Changkha, Hetshokha, and Pasakha.

Appendix 5. Names and institute affiliation of the interviewed personnel.

Department of Research and Development Services

Dr. Pema Choephyll, Director
Mr. GB Chettri, Joint Director for Research
Mr. Dorji Dradhul, Joint Director for Extension

Planning and marketing division

Mr. Choni Dhendup, Office Head

Natural Resources Training Institute (Lobesa)

Mr. Dorji Wangchuk, Director.
Mr. Jamba Gryeltshem, Head, Faculty of Agriculture.
Mr. Tulsi Gurung, Lecturer, Faculty of Agriculture.

European Union

Mr. Harry Franks, Co-Director, ESP Project.
Mr. Euclid D'souza, Extension and Training Specialist.

Helvetas/SDC

Mr. Erwin Koenig, Resident Coordinator.
Mr. Sonam Pelijore, Programme Officer.
Mr. Samuel B. Moser, Co-director at the Natural Resources Training Institute.

International Rice Research Institute (IRRI)

Mr. Julian Lapitan, IPMO Manager.
Dr. Glen Gregorio, Affiliate scientist.

Punakha dzonghkang Office

District officer

Deo Kumar Sharma (Kabiya)
Tandin Tshewang (Talo)
Glyeltshen
Sonam Dorji (Toewang)
Suraj Khawas
Jambay Ngyen (Gmma)
Glaylong (Dzomi)

RNR-RCs Jakar

Mr. Kinzang Wangdi, Program Director.
Dr. Walter Roder, Joint Program Director.

RNR-RC Bajo

Mr. Sangay Duba, Program Director.
Mr. Mahesh Ghimire, Senior research scientist.

Appendix 6. Names and institution affiliation of enumerators.

RNR-RC Yusipang
- Mr. Kencho Dukpa,
- Mr. P L Giri,
- Mr. Pushpa Raj Gurung,
- Mr. Karma Pelden,
- Mr. D B Rana,
- Mr. Rinchen and
- Mr. Gyem Thinley.

RNR-RC Bajo
- Mr. Karma,
- Mr. Jigme Norbu,
- Tanka Maya Pulami, and
- Kencho Wangdi.

RNR-RC Jakar
- Mr. Cheku Dorji,
- Mr. Wangda Drukpa
- Ms. Tshering Pem, and
- Ms. Rinchen Wangmo.

RNR-RC Khangma
- Mr. N B Adhikari,
- Mr. Phunstho, and
- Mr. L N Sharma.

Appendix 7.Cross-bred lines between TV and elite lines.

Cross designation	Parents	Lines/bulks
CARD20	Local Kaap/IR64	107
CARD21	Local Maap 1/IR64	235
CARD22	Ugey Maap/IR36	50
CARD24	Local Kaap/IR60	20
CARD25	Local Kaap/Selewah	27
CARD26	Ugey Maap2/IR36	94
CARD27	Ugey Maap3/IR36	34
CARD28	Local Maap/IR58	45
CARD29	Local Maap/IR56	40
IR56346	Wangdue Kaap(L)/BG90-2	175
IR56347	Wangdue Kaap(L)/CO25	140
IR56350	Wangdue Kaap(L)/IR24	214
IR56354	Wangdue Kaap(E)/CO25	226
IR56357	Wangdue Kaap(E)/IR24	187
IR56359	Wangdue Kaap(E)/IR52	135
IR58545	Bja Naab/B2982B-	22
IR58559	Bja Naab/BG94-1	53
IR58566	Bja Naab/China 1039	15
IR58567	Bja Naab/IR9202-	41
IR58568	Bja Naab/IR9758-	33
IR58569	Bja Naab/IR15636-	15
IR58570	Bja Naab/JKAU450-	26
IR58571	Bja Naab/RPKN2-	60
IR58606	Bja Naab/IR31386-	9
IR58615	Bja Naab/IR10041-	34
IR60016	Bja Naab/IR31868-	12
IR60018	Paro Maap/IR31868-	120
IR60019	Th. Dumbja/IR31868-	51
IR60020	Th. Maap/IR31868-	44
IR60021	Bja Maap/IR32429-	66
IR60023	Paro Maap/IR32429-	53
IR60025	Th. Dumbja/IR32429-	39
IR60026	Th. Maap/IR32429-	-
IR60035	Paro Maap/Milyang 54	30
IR60036	Th. Dumbja/M 54	65
IR60037	Th.Maap/M 54	85
IR60063	Bja Naab/85-3504	45
IR60068	Paro Maap/85-3504	37
IR60072	Th.Dumbja/85-3504	45
IR60073	Th. Maap/85-3504	138
IR61328	Bja Naab/IR41996-	274
IR61331	Paro Maap/IR41996-	293
IR61333	Th. Dumbja/IR41996-	191
IR61334	Th. Maap/IR41996-	177
IR61375	Th. Dumbja/Diamante Inia	40

IR61376	Th. Maap/Diamante Inia	9
IR61380	Paro Maap/N. Inia	45
IR61383	Th. Dumbja/N. Inia	40
IR61384	Th. Maap/N.Inia	20
IR61388	Bja Naab/Suweon 332	229
IR61390	Paro Maap/Suweon 332	229
IR61391	Kuchum/Vary Lava	4
IR61392	Paro Maap/Vary Lava	9
IR62448	Semtokha Maap2/IR43450-	65
IR62467	Attey/Suweon 358	149
IR62470	Punakha Maap/Suweon 358	154
IR62471	Semtokha Maap2/Suweon 3	-
IR62472	Sukhimey/Suweon 358	-
IR62473	Zakha/Suweon 358	99
IR62476	Semtokha Maap2/S 359	80
IR62478	Zakha/Suweon 359	55
IR62734	S 353//No.11/Th.Dumbja	48
IR62744	S 359//IR41996/Paro Maap	38
IR62745	S 359//IR41996/Th. Dumbja	84
IR62746	S 359//IR41996/Th. Maap	-
IR63332	Zakha/Akihikari	86
IR64237	Zakha/IR39739-	32
IR64429	Akihikari//Akihikari/Pun.I	-
IR64430	Akihikari//Akihikari/Sem.	29
IR65222	Attey/Akihikari	-
IR65239	Attey/YR3825-	135
IR65892	No. 11/Chummro	37
IR66408	Chhumro/IR55259-	74
IR66412	Chummro/IR60060-	152
IR66068	YR3825//YR3825/Barket	86
IR68136	Barket/Kochum	7
IR68142	IR64/Zawa Bondey	7
IR68146	JP5/Gyembja	9
IR68147	JP5/Kochum	7
IR68149	JP5/Zuchein	8
TOTAL		5740

Appendix 8. Fertilizer use recommendations.

(a). Traditional rice varieites.

Dzongkhags	N (Kg/acre)	P_2O_2 (Kg/acre)	K_2O (Kg/acre)
Thimphu	16-20	37971	0
Paro	20-24	37845	0-8
Wangdi	37981	37845	0
Punakha		37845	0
Trongsa	16-20	37845	0
Gaylegphug	16-20	37971	0-8
Chirang	16-20	37971	0-8
Other[1]	16-20	37971	0-8

(Source: Improved Rice Cultivation in Bhutan, Booklet for Commission Agents and Farmer Leaders)

[1]The remaining northern Dzongkhags where fertilizer trials have not yet been completed when these recommendations were made.

(b). Improved varieites

Dzongkhags	N (Kg/acre)	P_2O_2 (Kg/acre)	K_2O (Kg/acre)
Thimphu	20-32	37975	0-8
Paro	24-32	37971	0-8
Wangdi	20-32	37975	0-8
Punakha	24-32	37971	0-8
Gaylegphug	24-32	37975	37845
Chirang	28-36	16-24	0-8
Tashigang	20-28	16-24	0-8
Samchi	24-32	16-20	37849
Other[1]	34-32	16-24	0-8

(Source: Improved Rice Cultivation in Bhutan, Booklet for Commission Agents and Farmer Leaders)

[1]The remaining northern Dzongkhags where fertilizer trials have not yet been completed when these recommendations were made.

9 (a). High altitude zone.

RECOMMENDED PRACTICES FOR RICE PRODUCTION IN WARM TEMPERATE ZONES (HIGH ALTITUDES)

AREAS

These recommendations are for high altitude areas (1600-2600 m) that include Paro, Thimphu, and parts of Wangdue, Punakha, Tongsa, Lhuntshi and Tashigang.

VARIETIES

No.11

- Cold tolerant, high yielding, early maturing japonica rice.
- About 90 cm tall and matures 135-145 days after sowing.
- Short bold white grains with 66% milling (head rice) recovery.
- Difficult to thresh.
- Yields 5-7 t/ha under moderate management, but responds to fertilizers

Local Maaps

- Cold tolerant, tall stature, long growth duration, japonica types.
- Medium-short red grains, preferred for eating.
- Yields 2-3 t/ha under optimum management levels. Not responsive to higher levels of fertilizer.

CROP ESTABLISHMENT

Nursery sowing

- Optimum sowing date: March or first week of April
- Seed rate: 50-60 kg/ha
- Use clean and healthy seeds.
- Seedlings can be raised using semi-dry or dry bed methods (see leaflet on seedling production).

PREPARATION OF FIELD

Land preparation is one of the important factors that influences rice yield. It provides good physical, chemical, and biological conditions of the soil for optimum growth.

- Two or three ploughings are needed, followed by puddling and levelling.
- Plough thoroughly and then flood.
- Drain the water slightly and plough, rotovate or harrow as needed and level the field.
- A final puddling and levelling may be required just before transplanting.
- Repair and maintenance of bunds and the incorporation of chemical fertilizers, if any, should be done before the final puddling.

MANURE AND FERTILIZER

Farmers routinely apply FYM to rice in the high altitude areas. The rate of application varies widely from 5 to 20 t/ha. FYM contributes significantly to crop nutrition and soil condition. It is desirable to encourage the use of FYM.

Our recommendation is to apply about 5-8 t/ha FYM basally, and topdress with 35 kg N/ha 35-40 days after transplanting.

If adequate FYM is not available, apply 75:40:0 NPK kg/ha. Half the N and all the P should be applied as the basal dose. Topdress the remaining N 35-40 days after transplanting. For local varieties, limit N to 50 kg/ha to prevent lodging.

TRANSPLANTING

Transplanting time: Mid-May to mid-June

Traditional random method can be used if:

Weed pressure is expected to be low.
Butachlor will be used.
The terraces are narrow and small.

Line planting should be done if weeding will be carried out with a rotary weeder.
Use a rope to give a row spacing of 20 cm and within-row spacing of 15-20 cm.

A plant density of 25-35 per square metre is optimum. Transplant local varieties at a closer spacing (15 x 15 cm), as they do not tiller well.

WEED CONTROL

Weeds are serious competitors of rice. They compete for water, nutrients and sunlight, and reduce grain yields.

Where weed pressure is low or moderate, 2 hand weedings 20 and 40 days after transplanting are sufficient. If hand weeding is to be done, plants should be closely spaced and the first weeding performed no later than 30 days after transplanting.

Where weed pressure is high, use line planting and rotary weeding. Two rotary weedings 20 and 40 days after planting are recommended. In areas where shochum is a severe problem, additional hand weedings may be required.

If there is no or little shochum but weed pressure is high, Butachlor is a very effective alternative to rotary weeding. It is applied 3-6 days after transplanting at the rate of 30-40 kg/ha of 5% "Punch" granules.

If shochum is a major problem it can be controlled by Sanbird applied at 25-35 kg/ha 4-6 days after transplanting. Alternatively apply NC 311 at 25-30 kg/ha.

As weeding is laborious, and the use of herbicides is undesirable, there must be emphasis on indirect complementary weed control methods like good land preparation, proper water management, and use of weed-free seedbeds and seeds.

WATER MANAGEMENT

After transplanting keep the water level low for 4-7 days until the seedlings recover. Water level should then be increased as the crop grows ensuring adequate water from tillering to flowering.

If the supply of water is limited, continuous flooding is not possible. In this case irrigate at short intervals but do not let the field become excessively dry and crack. Flowering is the most critical stage when rice should not be exposed to moisture stress.

Drain water from the field 10-15 days before harvest to enhance ripening.

PLANT PROTECTION

Insect pest and diseases are normally not a major problem in rice at high altitudes.

HARVEST

Under normal conditions harvesting begins from the first week of October. Harvest the crop when at least 85% of the upper portion of panicles turns straw coloured. Some leaves and stems may still be green at grain maturity, particularly for No.11.

Local varieties shatter very easily, and timely harvest will minimize grain losses.

For further information contact
Mahesh Ghimiray, Field Crops Sector, RNR-RC, Bajo

Appendix 9 (b). Medium altitude zone.

RECOMMENDED PRACTICES FOR RICE PRODUCTION AS A MAIN CROP IN DRY AND HUMID SUBTROPICAL ZONES (MEDIUM ALTITUDES)

These recommendations are for medium altitude (700-1500 m) areas that include Wangdue, Punakha, parts of Trashigang-Monggar in the dry zone and Tsirang, Dagana, parts of Sarpang, Samtse, Samdrup Jonkhar in the humid zone.

VARIETIES

IR 64

High yielding tropical semi-dwarf variety
Matures 145-150 days after sowing.
Grain quality similar to local white rice
Milling recovery 65%.
Slender white grains.
Yields 5-7 t/ha under average conditions, but responds to higher fertilisation.

Milyang 54

Japonica/indica cross which originally came from Korea.
About 95 cm tall and matures 140-145 days after sowing.
Slender white grains, good eating quality.
Higher yielding than IR64; yields 6-9 t/ha under moderate management.
Susceptible to sheath blight particularly in high rainfall humid areas.

IR 20913

An advanced selection from the cross between Bhutanese (Paro) white rice and an IRRI line.
About 100 cm tall and matures 120-130 days after sowing.
Yields over 7.5 t/ha under good management.
Moderate cold-tolerance at flowering, and early maturity make it suitable for late planting as the main crop.

CROP ESTABLISHMENT

Nursery sowing

Optimum sowing date: May in dry zone, June in humid zone.
Seed rate: 50-60 kg/ha.
Use clean and healthy seeds.
Seedlings can be raised using wet or semi-dry bed methods (see seedling production leaflet).

PREPARATION OF FIELD

Land preparation is one of the important factors that influences rice yield. It provides good physical, chemical, and biological conditions of the soil for optimum growth.

Two or three ploughings are needed, followed by puddling and levelling.
Irrigate the field before ploughing, if dry.

Plough thoroughly and then flood.
Drain the water slightly and plough, rotovate or harrow as needed
A final puddling and levelling may be required just before transplanting.

Repair and maintenance of bunds and the incorporation of chemical fertilizers, if any, should be done before the final puddling.

MANURES AND FERTILIZERS

Farmers routinely apply FYM to rice in the medium altitude areas ranging from 5 to 20 t/ha. FYM contributes significantly to crop nutrition and soil condition.

Our recommendation is to apply about 5-8 t/ha FYM basally, and topdress with 35 kg N/ha 35-40 days after transplanting.

If adequate FYM is not available, apply 75:40:0 NPK kg/ha. Half the N and all the P should be applied as the basal dose. Topdress the remaining N 35-40 days after transplanting. For local varieties, limit N to 50 kg/ha to prevent lodging.

Sesbania aculeata (Dhaincha) can be grown for 6-8 weeks then incorporated as green manure during land preparation. Sow Dhaincha at a rate of 50-60 kg/ha in April after harvesting wheat or mustard. Topdress 35 kg N/ha at PI for higher yields.

TRANSPLANTING

Transplanting time: June in dry zone, July in humid zone

Traditional random method can be used if:
Weed pressure is expected to be low.
Butachlor will be used.
The terraces are narrow and small.

Line planting should be done if weeding will be carried out with a rotary weeder.
Use a rope to give a row spacing of 20 cm and within-row spacing of 15-20 cm.
A plant density of 25-35 per square metre is optimum.

WEED CONTROL

Where weed pressure is low or moderate, 2 hand weedings 20 and 40 days after transplanting are sufficient. Plants should be closely spaced and the first weeding done no later than 30 days after transplanting.

Where weed pressure is high, use line planting and rotary weeding. Two rotary weedings 20 and 40 days after planting are recommended.

If there is no or little shochum but weed pressure is high, Butachlor is a very effective alternative to rotary weeding. It is applied 3-6 days after transplanting at the rate of 30-40 kg/ha of 5% "Punch" granules.

If shochum is a major problem it can be controlled by Sanbird applied at 25-35 kg/ha 4-6 days after transplanting. Alternatively apply NC 311 at 25-30 kg/ha.

As weeding is laborious, and the use of herbicides is undesirable, there must be emphasis on indirect complementary weed control methods like good land preparation, proper water management, and use of weed-free seedbeds and seeds.

WATER MANAGEMENT

After transplanting keep the water level low for 4-7 days until the seedlings recover. Water level should then be increased as the crop grows.

If the supply of water is limited, continuous flooding is not possible. In this case irrigate at short intervals but do not let the field become excessively dry and crack. Flowering is the most critical stage when rice should not be exposed to moisture stress.

Drain water from the field 10-15 days before harvest to enhance ripening.

PLANT PROTECTION

Insect pest and diseases are normally not a major problem in rice at medium altitudes.

HARVEST

Under normal conditions harvesting begins from the first week of October. Harvest the crop when at least 85% of the upper portion of panicles turns straw coloured. Some leaves and stems may still be green at grain maturity, particularly of improved varieties.
Local varieties shatter very easily, and timely harvest will minimize grain losses.

For further information contact
Mahesh Ghimiray, Field Crops Sector, RNR-RC, Bajo

Appendix 9 (c). Low altitude zone.

RECOMMENDED PRACTICES FOR RICE PRODUCTION FOR WET SUBTROPICAL ZONES (LOW ALTITUDES)

These recommendations are made for the low altitude (150-600 m) southern belt that include Sarpang, Samtse and Samdrupjonkhar for irrigated rice culture.

VARIETIES

BR 153

- BR 153 is a high yielding, tropical semi-dwarf variety bred in Bangladesh.
- It is 100-110 cm tall and matures in 140-150 days.
- It has good resistance to diseases and pests and is tolerant of poor soils and management.
- It has slender white grains.
- Yields of 2-3 t/acre can be obtained under average management conditions.

BW 293

- BW 293 is a tropical, high yielding variety developed in Sri Lanka.
- It is 75-85 cm tall and matures in 140-150 days from sowing
- It has slender white grains with intermediate to high amylose content.
- It has higher yield potential than BR 153 under similar input levels.

CROP ESTABLISHMENT

Nursery sowing

- Optimum sowing date: June .
- Seed rate: 50-60 kg/ha.
- Use clean and healthy seeds.
- Seedlings can be raised using wet or semi-dry bed methods (see rice seedling production leaflet).

PREPARATION OF FIELD

Land preparation is one of the important factors that influences rice yield. It provides good physical, chemical, and biological conditions of the soil for optimum plant growth.

- Two or three ploughings are needed, followed by puddling and levelling.
- Irrigate the field before ploughing, if dry.
- Plough thoroughly and then flood.
- Drain the water slightly and plough, rotovate or harrow as needed to break clods, bury weeds and to puddle and level the field.
- A final puddling and levelling may be required just before transplanting.

Repair and maintenance of bunds and the incorporation of chemical fertilizers, if any, should be done before the final puddling.

MANURES AND FERTILIZERS

FYM contributes significantly to crop nutrition and soil condition. It is desirable to encourage the use of FYM.

Our recommendation is to apply about 5-8 t/ha FYM basally, and topdress with 35 kg N/ha 35-40 days after transplanting.

If adequate FYM is not available, apply 80:40:30 NPK kg/ha. Half the N and all the P should be applied as the basal dose. Topdress the remaining N 35-40 days after transplanting. For local varieties, limit N to 50 kg/ha to prevent lodging.

Sesbania aculeata (Dhaincha) can be grown for 6-8 weeks then incorporated as green manure during land preparation. Sow

Dhaincha at a rate of 50-60 kg/ha in May.
Topdress 35 kg N/ha at PI for higher yields.

TRANSPLANTING

Transplanting time: July.

Traditional random method can be used if:
- Weed pressure is expected to be low.
- Butachlor will be used.
- The terraces are narrow and small.

Line planting should be done if weeding will be carried out with a rotary weeder.
- Use a rope to give a row spacing of 20 cm and within-row spacing of 15-20 cm.

A plant density of 25-35 per square metre is optimum.

WEED CONTROL

Weeds are serious competitors of rice. They compete for water, nutrients and sunlight, and reduce grain yields.

Where weed pressure is low or moderate, 2 hand weedings 20 and 40 days after transplanting are sufficient. If hand weeding is to be done, plants should be closely spaced and the first weeding performed no later than 30 days after transplanting.

For weeds other than shochum, Butachlor is very effective. It is applied 3-6 days after transplanting at the rate of 30-40 kg/ha of 5% "Punch" granules.

As weeding is laborious, and the use of herbicides is undesirable, there must be emphasis on indirect complementary weed control methods like good land preparation, proper water management, and use of weed-free seedbeds and seeds.

WATER MANAGEMENT

After transplanting keep the water level low for 4-7 days until the seedlings recover. Water level should then be increased as the crop grows ensuring adequate water from tillering to flowering.

If the supply of water is limited, continuous flooding is not possible. In this case irrigate at short intervals but do not let the field become excessively dry and crack. Flowering is the most critical stage when rice should not be exposed to moisture stress.

Drain water from the field 10-15 days before harvest to enhance ripening.

PLANT PROTECTION

Insect pests and diseases are a major concern due to high temperature and humidity. Integrated pest management approach is recommended which involves varietal resistance, cultural and biological control methods, and use of pesticides at a need based level.

HARVEST

Under normal conditions harvesting begins from the first week of October. Harvest the crop when at least 85% of the upper portion of panicles turns straw coloured. Some leaves and stems may still be green at grain maturity, particularly of improved varieties.

Local varieties shatter very easily, and timely harvest will minimize grain losses.

For further information contact
Mahesh Ghimiray, Field Crops Sector, RNR-RC, Bajo

10 (a). Double rice crop.

RECOMMENDED PRACTICES FOR RICE DOUBLE CROPPING DRY SUBTROPICAL AND ZONES (MEDIUM ALTITUDES)

These recommendations are made for the medium altitude areas (upto 1500 m) particularly in Wangdue-Punakha valley and Trashigang-Monggar.

FIRST CROP

VARIETIES

No. 11

- Cold tolerant, high yielding, early maturing, Japonica rice.
- It has good seedling cold tolerance, however symptoms like yellowing of leaves and stunting may occur under very low temperature.
- It is about 90 cm in height and matures in 160 days from sowing.
- It has yield potential of over 3 t/acre under good management but it is difficult to thresh.

Barket

- Cold tolerant, high yielding, early maturing, japonica rice.
- It has good seedling cold tolerance and produces vigorous seedlings under polytunnel nursery.
- It is 90-95 cm in height and matures in about 155 days.
- It is very easy to thresh unlike No.11.
- It has a yield potential of over 2.5 t/acre under good management.

CROP ESTABLISHMENT

- First crop can be established either by transplanting or direct seeding.

Transplanting

- First week of Feb. is the recommended time to sow nursery.
- Use a seed rate of 25-30 kg/acre.
- Raise seedlings using a polytunnel nursery bed.
- Raising of seedlings in polytunnel nursery (see leaflet on rice seedling production)

Time of transplanting

- The ideal transplanting time is the second week of March.
- The method of transplanting, either in line or at random, should be decided depending upon the weed control method to be adopted and labour availability.

Direct Seeding

Direct seeding greatly reduces labour cost in establishing a crop of rice. A direct seeded crop of rice also matures about a week earlier than transplanted. However, the general requirements for successful direct seeding are good rice variety, good land preparation, good weed control, and good water supply and management. Direct seeding can be done in 2 ways:

Dry Furrow Seeding

- Land preparation should be done in dry soil to get a well pulverized seed bed as in a dry bed nursery.
- Open up furrows 2-3 cm deep and 20-30 cm apart
- Drop unsoaked seeds evenly or place 4-8 seeds at a distance of 10-15 cm along the furrow.
- After sowing cover the seeds lightly with fine soil.

Irrigate the field lightly after sowing. Do not keep standing water in the field as excess water deprives the seeds of oxygen and they eventually die. Keep the field moist until the seeds germinate.

Keep the field saturated till seedlings attain a height of about 10 cm. Increase the water level gradually.

Use a seed rate of 40-50 kg/acre.

Optimum sowing time is the first half (1-15) of March.

Wet Broadcast Seeding

Prepare the land as for any transplanted rice crop. However, field should be properly levelled for efficient drainage.

After final land preparation, allow the mud to settle overnight to avoid sinking of seed. Keep water level to the minimum.

Broadcast pre-germinated seeds (soaked for 24 hours and incubated for 36-48 hours) evenly. Walk backwards while seeding and avoid making too many mud depressions that collect water and rot the seed.

Keep the water level as minimum as possible till the seeds secure roots and emerge (2-5 days but may take longer if temperature is low). Then, increase the water level gradually as seedlings grow in height.

Use a seeding rate of 70-90 kg/ha.

First half of March is the optimum seeding time.

Weed control is the biggest challenge of this method. Butachlor is not suitable as it suppresses emergence and arrests seedling growth at early stages. However, Sanbird and NC 311 can be successfully applied 5-7 days after seeding without affecting rice growth.

Other activities like field preparation, manures and fertilizers, weed control etc are similar to a normal crop of rice.

SECOND CROP

VARIETY

IR 20913

It is an advanced selection from the cross between Bhutanese white rice and an IRRI line.

It is about 100 cm tall and mature in about 130-140 days from sowing.

It has an yield potential of over 3 t/acre under average to good management conditions.

It has moderate cold tolerance at seedling and flowering stages and is also good for late planting of the normal season crop.

CROP ESTABLISHMENT

Nursery sowing : June 15 - June 30
Seed rate : 20-25 kg/acre
Nursery raising : Seed selection as for the first crop. Seedlings could be raised either by wetbed or semi-drybed methods.

TRANSPLANTING

Time of transplanting : July 15 - July 30

Transplant 20-30 days old seedlings using 2-3 seedling/hill. Maintain closer spacing as recommended for the first crop.

Other practices are similar as for a normal rice crop.

For further information contact
Mahesh Ghimiray, Field Crops Sector, RNR-RC, Bajo

10 (b). Mustard in wetland.

Mustard Cultivation in Wetland Production System

VARIETY

Type 9 or T9

Early maturing variety of Indian origin.
Matures in 90-100 days.
Semi-spreading growth habit and grows to a height of 100-110 cm.
Seeds are medium in size, brownish-black in colour and contain 40-42% oil.
Yield of 0.75-1.0 t/ha under good management conditions.
Recommended for medium altitude valleys (<1900 m) and low altitude foothills.

M27

Early maturing variety of Indian origin.
Matures in 85-95 days.
Semi-spreading type growing to a height of 85-90 cm.
Seeds are medium in size and contain 43-45% oil.
Yield of 0.5-1.0 t/ha under good management conditions.
Recommended for medium altitude valleys (<1900 m) and low altitude foothills.

BSA

Late maturing variety of Pakistani origin.
Matures in 150-160 days.
Grows to a height of 115-125 cm.
Yield of 1.0-2.0 t/ha under good management conditions.
Recommended upto an altitude of 2300 m and for rice and maize-based systems.

PT 30

Medium maturing variety from India.
Matures in 120-130 days.
Grows to a height of 75-90 cm.
Yield of 0.75-1.0 t/ha under good management conditions.
Recommended upto an altitude of 2000 m and for rice and maize-based systems.

CLIMATE

Best yields are generally obtained when early plant establishment and growth occurs under slightly warmer temperatures, with flowering and seed filling taking place at cooler temperatures.

SOILS

Type 9 Mustard can be grown under a wide range of soil conditions varying from sandy loam to clay loam. It thrives best on light loam soils. It neither tolerates waterlogging conditions nor does well on heavy soils. A soil with neutral pH is ideal for growth and development.

FIELD PREPARATION

Irrigate 7-10 days before sowing to ensure good germination and early seedling vigour. Plough deeply once, followed by second and possibly third ploughing using a local plough. Planking may be given after each ploughing to make the seed bed fine.

SEEDS AND SOWING

Selection of Seed: Use healthy seeds of a recommended variety. Treat the seeds with Thiram @ 2 g/kg seed to protect seedlings from diseases such as root rot and wilt.
Seed rate: 7.5-10 kg/ha.
Sowing time: October-November. It is likely that an earlier sown crop would produce higher yields. If sowing is delayed there is danger of aphid attack.

Method of sowing: Broadcast the seeds uniformly in a well-pulverised field. Light planking should be given to cover the seeds. Seed depth of 2-3 cm is optimal.

Spacing: For line sowing use a spacing of 30 cm between rows and 5-10 cm within rows.

MANURE AND FERTILIZER

Apply 2.5-5 t/ha of FYM as a basal dose, then 35 days after sowing topdress with 50 kg/ha nitrogen.

If adequate FYM is not available, apply chemical fertilizers @ 100:50:0 NPK kg/ha. Half the N and all the P should be applied as a basal dose. The remaining N should be topdressed 35 days after sowing.

AFTER CARE

Thin the mustard 15-20 days after sowing to give a plant-to-plant spacing of 5-10 cm. Intercultural operations should, if possible, be done 20-25 days after sowing to remove weeds and conserve moisture.

IRRIGATION

Generally two irrigations are sufficient:

First irrigation: at flowering stage, 20-25 days after sowing.

Second irrigation: at fruiting/podding stage, 50-55 days after sowing.

PLANT PROTECTION

Mustard Aphid

This aphid is the most destructive pest of mustard. It is pale green, soft bodied and 1-2 mm long. Adults and nymphs suck cell sap from various plant parts affecting seed yield and oil content considerably.

Control:

Early sowing - first fortnight of October.
Removal of early-infected plant parts.
Spray Malathion 50 EC @ 1 ml/litre of water.

Mustard Sawfly

Adults are orange yellow wasps with smoky wings and black head and legs. Larvae are yellowish green or dark green with five lateral stripes. They appear in the early stages of the crop in October or November. The larvae make irregular holes in the leaves. Control: Spray Malathion 50EC @ 1 ml/litre of water.

Alternaria Blight

Small light brown circular spots appear on the cotyledon leaves, turning black in the advanced stage. Small circular brown or blackish spots appear on leaves, increase in size and multiply rapidly, forming dark brown concentric rings.

Control:

Spray the crop with Dithane M-45 weekly. Use 2 kg fungicide suspended in 1000 litres of water per hectare.

White Rust

Small, white raised pustules appear on the leaves, stems, inflorescence and floral parts. These pustules coalesce to form large patches.

Control:

Apron SD-35 (Ridomil) 0.2% as seed dressing delays the primary infection.
Spray Dithane M-45 @ 1.5 kg/ha at 15-day intervals.

Club root

Plants become stunted with pale green or yellowish leaves. Small to large, spindle or spherical shaped knots or clubs appear on the main or lateral roots.

Control:

Long term crop rotation.
Use resistant varieties.

HARVESTING AND THRESHING

Harvest when 75% of pods turn yellowish. To minimise shattering losses, harvest in the morning when the pods are slightly damp with the dew. Stack the mustard in bundles to dry in the sun for a few days, and then thresh manually. For safe storage, clean the seed and dry in the sun to reduce the moisture content to less than 8 %.

For further information contact
Mahesh Ghimiray, Field Crops Sector, RNR-RC, Bajo

Appendix 11. Recommended practices for rice ratooning.

RECOMMENDED PRACTICES FOR RICE RATOONING

In areas where adequate water is available after the first crop season, rice ratooning could be practised as an alternative to raising of the second crop in rice double cropping. The ratoon crop matures earlier and requires less labour and water inputs. Water use efficiency is high. Early maturing, high yielding first crop varieties like No.11 and Barket are suitable for ratooning.

The success of a good ratoon crop depends on the care with which the first crop is cultivated in the growing season. Agronomic practices for the first crop determine the success of ratooning and grain yields of ratoonable varieties. Variations in soil, water, light and temperature influence ratooning ability. Tiller development is highly influenced by the carbohydrates that remain in the stubbles and roots after harvest and the level of nitrogen in the soil. Varieties with thick culms/stems store more carbohydrates and are more suitable for ratooning.

AGRONOMIC PRACTICES

Time of harvest

The best time to harvest the main crop for raising a good ratoon crop is when its culms or stems are still green. Stalks should be cut before the main crop is fully matured and dried up so that the stems are physiologically viable for ratoon tillering.

Spacing

The effect of spacing on grain yield of the main and ratoon crops is different from one variety to another. In general, the optimum spacing for good ratoon yield is 20 x 20 cm.

Cutting height

Interactions between varieties and cutting height exist; some varieties tiller better when cut high, while others produce better tillers when cut at lower levels. For short-statured varieties like No.11 and Barket, a cutting height of 15-20 cm is optimum. Further reducing the cutting height increases the number of missing hills in the ratoon crop.

Water management

Excess flooding immediately after main crop harvest can cause rotting of stubbles and can retard tiller formation. Keep the field drained but moist for about 10 days after harvest to promote sprouting and tillering. Thereafter, irrigate the field as in the main crop.

Fertilizer management

Studies on fertilizer requirements show that a ratoon crop needs nitrogen at the rate of 75% of the main crop. P and K are usually adequate and do not respond upon application. For Wangdi-Punakha valley, topdress N at the rate of 50 kg/ha after 20-30 days of harvesting the main crop.

Weed control

Weed intensity in a ratoon crop depends very much on the control measures applied to the main crop. A thorough handweeding should be carried out 20-30 days after harvesting of the main crop during the time of topdressing.

HARVESTING

Harvest the ratoon crop when over 80% of the grains are matured and turn straw-coloured.

YIELD

On an average, ratoon rice can give a yield roughly equivalent to 40% that of the main crop, with 40% reduction in crop duration.

For further information contact
Mahesh Ghimiray, Field Crops Sector, RNR-RC, Bajo

Appendix 12. Recommended practices for direct seeding.

RECOMMENDED PRACTICES FOR DIRECT SEEDING OF RICE

Direct seeding greatly reduces the labour cost in establishing a crop of rice. Under ideal conditions, similar high yields can be obtained with direct seeded and transplanted crops. A direct seeded crop of rice also matures about a week earlier than transplanted. However, the general requirements for successful direct seeding are a good rice variety, good land preparation, good weed control, and good water supply and management.

VARIETIES

Any short-statured, early-to-medium maturing varieties are suitable for direct seeding. All of the so far recommended improved varieties can be successfully direct seeded. However, IR20913, IR 64, No.11, Barket and BR153 are particularly suitable. Tall Local varieties such as Zakha, Attey and Maaps, are not suitable as they lodge severely at maturity.

CROP ESTABLISHMENT

One of the most common methods for direct seeding is wet broadcast seeding.

Wet Broadcast Seeding

Prepare the land as for a transplanted rice crop. It is particularly important that the field should be properly levelled for efficient drainage.

After final land preparation, allow the mud to settle overnight to avoid sinking of the seed. Keep the water level to a minimum.

Broadcast pre-germinated seeds (soaked for 24 hours and incubated for 36-48 hours) evenly. Walk backwards while seeding and avoid making too many mud depressions that collect water and rot the seed.

Keep the water level as minimum as possible till the seeds secure roots and emerge. This should take 2-5 days, but may be longer if the temperature is low. Then increase the water level gradually as seedlings grow in height.

Seed rate

Use a seed rate of 70-90 kg/ha.

Seeding time

Depending on the cropping season, variety and growing area, direct seeding should be done 15-20 days prior to the recommended transplanting time.

Weed control

Weed control is the biggest challenge in a direct seeded crop. Good land preparation, proper water management and optimum plant stand helps in reducing weed pressure to a large extent. Keep the field weed-free by hand weeding. The number of weedings depends upon the weed pressure in any particular locality or cropping season. Butachlor is not suitable as it suppresses emergence and arrests seedling growth at early stages. If available, Sanbird and NC 311 can be applied 5-7 days after seeding without affecting rice growth.

OTHER CULTURAL PRACTICES

Other cultural practices are the same as in a transplanted crop.

For further information contact
Mahesh Ghimiray, Field Crops Sector, RNR-RC, Bajo

Appendix 13. Wetland and dryland area in the survey, 2002.

Altitude	Wet land (ha)	Dry land (ha)	Total (ha)	% of land		
				Wet land	Dry land	Total
High	87.5	27.5	115.0	76.1	23.9	100.0
Medium	68.0	16.1	84.1	80.8	19.2	100.0
Low	79.5	36.8	116.3	68.4	31.6	100.0
Total	235.0	80.4	315.5	74.5	25.5	100.0

(Source: Impact assessment survey, 2002)

Appendix 14. Households adopting different groups of rice varieties, 2002.

Households adopting	Number of households				% of households			
	High	Medium	Low	Overall	High	Medium	Low	Overall
TV only	24.0	34.0	41.0	99.0	22.9	41.5	68.3	40.1
TV and MV	33.0	34.0	12.0	79.0	31.4	41.5	20.0	32.0
MV only	48.0	14.0	7.0	69.0	45.7	17.1	11.7	27.9
All households	105.0	82.0	60.0	247.0	100.0	100.0	100.0	100.0

(Source: Impact assessment survey 2002)

Currently, only 2.5% of the national rice area is adopted to BMV. The increase in the adoption of BMV overtime is expected as these are newest varieties that have become available only during the last five years. These varieties are higher yielding than other groups of MV and have locally preferred traits. Hence, as farmers become more familiar with the varieties it is reasonable to assume that their adoption and benefits will also increase over time.

The production gain if BMV adoption increases from the current 2.5% to 25% is presented in Figure 7 (see Appendix 25 for data). The figure illustrates the magnitude of gain in production as a result of BMV adoption. If we assumed 15% adoption of BMV (replacing OMV) in the high and medium altitude zone only, the gain is estimated at 3,000 t. If BMV is assumed to replace TV in 30% of the area in the high and medium altitude zones, it would lead to an increase in production of over 7,500 t.

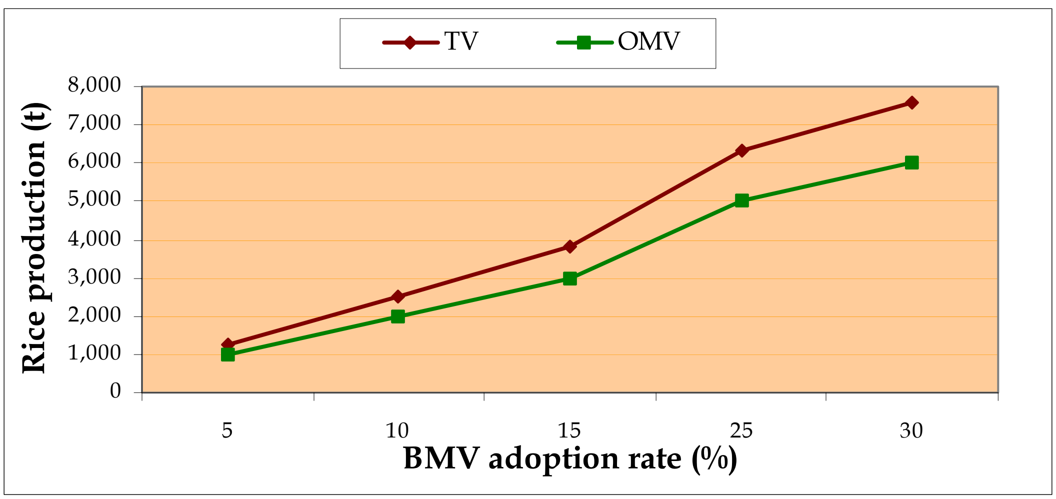


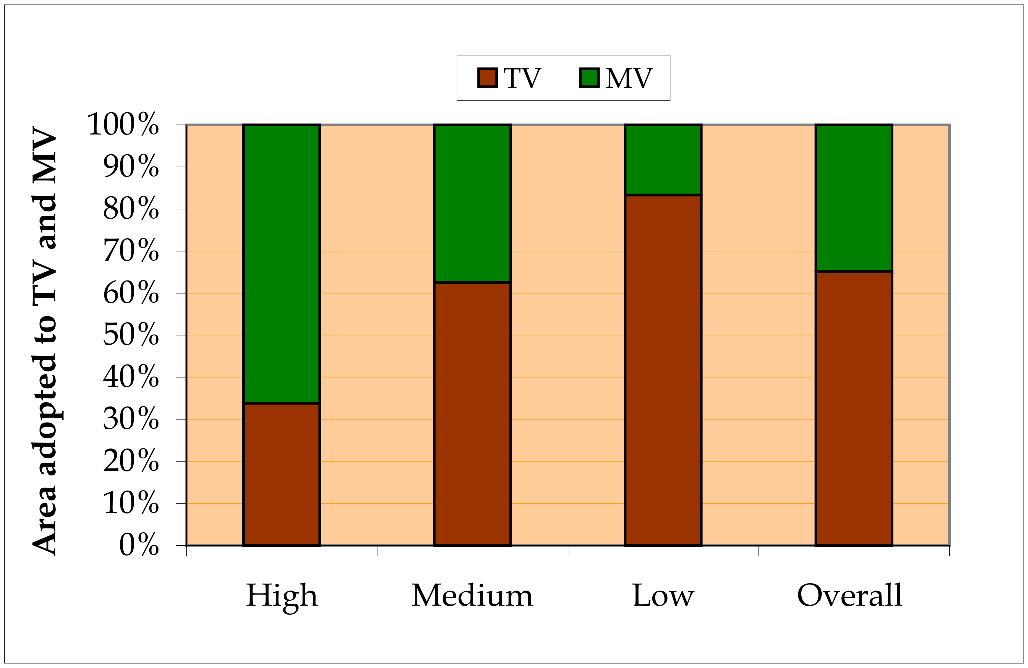
Figure 7. Estimation of increase in rice production with different BMV adoption rates.

(Source: Impact assessment survey, 2002).

[a] Estimation is based on the rice area of the high and medium altitude zones. The BMV are not adopted in the low altitude zone.

Note: The yield difference of BMV over IMV is small (0.14 t/ha).

Appendix 15. Wetlands rice area under different rice varieties, 2002.



Appendix 16. Area under each modern rice vareities, 2002.

(a). IMV group.

Altitude	% of IMV planted to varieties	
	IR 64	IR 20913
High	24.39	75.61
Low	100.00	0.00
Medium	93.58	6.42
Total	92.52	7.48

(b). OMV group.

Altitude	% of OMV planted to varieites				
	Khamgma Maap	No. 12	Khumal 3	BR 154	Unidentified MV
High	77.30	17.17	0.00	0.00	5.53
Low	0.00	0.00	0.00	69.44	30.56
Medium	14.19	53.63	19.72	0.00	12.46
Total	61.72	15.82	0.83	11.62	10.01

(c). BMV group.

Altitude	% of BMV area planted to varieties		
	Bajo Kaap 1& 2	Bajo Maap 1& 2	Yusi Ray Maap
High	33.96	40.88	25.16
Medium	44.42	55.58	0.00
Total	41.46	51.42	7.12

(Source: Impact assessment survey 2002).

Appendix 17. Yields for different groups of rice varieties, 2002.

Altitude	Yield level (t/ha)				
	BMV	IMV	OMV	MV	TV
High	4.07	3.49	3.20	3.26	3.21
Medium	4.67	4.36	3.43	4.26	3.08
Low	n/a	3.46	2.62	2.74	1.64
Overall	4.43	4.29	3.17	3.62	2.84

(Source: Impact assessment survey 2002).

Appendix 18. Yields for each modern rice varieties, 2002.

(a). IMV group.

Altitude	Yield (t/ha)	
	IR 64	IR 20913
High	2.45	3.83
Medium	4.38	4.01
Low	3.46	n/a
Overall	4.32	3.95

(b). OMV group.

Altitude	Yield (t/ha)				
	No.11	Khamgma Maap	BR 153	Khumal 2	Unidentified MV[a]
High	3.82	3.05	n/a	n/a	3.12
Medium	3.59	3.71	n/a	1.90	3.63
Low	n/a	n/a	2.45	n/a	3.01
Overall	3.76	3.07	2.45	1.90	3.18

(c). BMV group.

Altitude	Yield (t/ha)		
	Bajo Maap 1&2	Bajo Kaap 1&2	Yusi Ray Maap
High	3.57	4.47	3.37
Medium	4.21	5.07	n/a
Overall	4.07	4.82	3.37

[a] Average yield of varieites not identified individually.

(Source: Impact assessment survey 2002).

Appendix 19 . Cost of production for different groups of rice varieities, 2002.

Inputs	High (Nu/ha)		Medium (Nu/ha)		Low (Nu/ha)		All households (Nu/ha)	
	TV	MV	TV	MV	TV	MV	TV	MV
Urea	517.5	462.6	649.8	709.6	21.9	0.0	396.4	390.7
Suphala	25.2	99.8	90.3	85.6	27.6	0.0	47.7	61.8
Herbicide	917.5	718.6	593.6	645.5	20.8	0.0	510.6	454.7
Pesticide	112.1	77.6	15.7	6.3	13.7	13.1	47.2	32.3
Seed cost	6.3	5.3	18.5	13.1	12.6	0.0	12.5	6.1
Farm Machinery	113.8	194.8	196.5	150.5	16.9	417.2	109.1	254.2
Other inputs	0.0	98.7	42.4	26.3	13.5	292.0	18.6	139.0
All inputs cost	**1692.4**	**1657.3**	**1606.7**	**1636.9**	**127.0**	**722.3**	**1142.0**	**1338.8**

(Source: Impact assessment survey 2002).

Appendix 20. Average retail price (per kilo) of milled rice, 2002.

Dzongkhag (districts)	Red Rice	round rice	Local White Rice	Bhog White Rice	S F White Rice	Raw Fine White Rice	Common White Rice
Tairang	19.04	*	23.10	*	*	*	*
Paro	31.38	*	30.50	35.38	12.65	12.68	10.00
Punakha	25.9	*	23.8	12.3	15.0	*	12.0
Lhuntse	28.08	*	26.67	26.37	15.33	13.78	9.75
Dagana	*	*	*	25.00	*	12.00	10.00
Mongar	20.00	*	23.50	24.05	22.36	12.99	11.56
S/Jongkhar	*	*	12.00	*	10.00	11.78	11.00
tphu	24.58	*	25.38	*	*	*	*
Gelephu	10.58	10.74	10.46	14.86	9.50	9.20	8.93
Tashigang	10.90	*	*	20.00	13.35	12.00	10.00
Samtse	10.97	*	11.57	20.52	9.29	*	8.35
Average	20.16	10.74	20.77	22.31	13.44	12.06	10.17

(Source: Planning Department 2002).
* not available.

Appendix 21. Farm-gate price of milled rice, 2002 [a].

Altitude	MV white[b]	MV red[c]	TV
	Nu/kg	Nu/kg	Nu/kg
High	25.5	24.4	19.3
Medium	18.9	20.4	17.7
Low	10.1	n/a	12.3
Overall	18.9	23.3	17.8

(Source: Impact assessment survey, 2002).

[a] The farm-gate price of rice is based on 129 hosueholds who reported selling rice by varieties. Fourty one hosueholds fromthe High altitude zones, 81 households from medium and seven households from the Low altitude are represented.

[b]MV-white rice varietes sold were IR 64, IR 20913, Bajo Kaap 1 & 2, BR 153 and unidentified MV. [c]The MV-red sold were Bajo Maap 1& 2, and Khangma Maap.

The average price per kilo of milled rice is Nu. 19.97. The average paddy per kilo is Nu. 11.98 (19.97*0.6, coversion ratio of 60% from paddy to milled rice is used).

Appendix 22. Households and wetland farm size among the MV adopters, 2002.

Altitude	Family size		Wet land farm size	
	MV adopter	non-adopter	MV adopter	non-adopter
High	8.7	7.8	0.21	0.32
Medium	8.0	8.7	0.23	0.20
Low	7.4	7.4	0.79	0.67
Overall	8.2	7.9	0.34	0.29

(Source: Impact assessment survey 2002).

Appendix 23. Indications of changes in the rural households in last 5-8 years, 2002 .

Indicators	Households adopting		
	MV only	TV only	TV&MV
Self sufficiency			
Increased	28.5	30.4	41.1
Decreased	22.2	63.9	13.9
Constant	24.4	61.0	14.6
Rice production			
Increased	30.0	29.4	40.6
Decreased	21.8	65.5	12.7
Constant	27.6	51.7	20.7
Overall income			
Increased	28.5	35.5	36.0
Decreased	4.2	83.3	12.5
Constant	38.5	46.2	15.4
Home improvement			
Increased	25.9	40.5	33.5
Decreased	0.0	66.7	33.3
Constant	25.5	44.7	29.8
Pilgrimage			
Increased	42.9	11.4	45.7
Decreased	15.4	76.9	7.7
Constant	29.0	53.2	17.7
Livestock			
Increased	28.1	36.8	35.1
Decreased	27.3	38.0	34.7
Constant	23.1	50.0	26.9
Farm machinery			
Increased	13.0	40.7	46.3
Decreased	0.0	100.0	0.0
Constant	9.6	58.5	31.9
Farm Knowledge			
Increased	29.7	32.3	38.0
Decreased	0.0	50.0	50.0
Constant	13.5	63.5	23.1

Appendix 24. Increase in production and net returns from new rice technologies.

(a). Per hectare estimations

Altitude	Yield (t/ha)		Yield difference	MV adoption	difference MV over TV (nu/ha)		
	TV	MV			Gross return	Cost	Net return
High	3.21	3.26	0.05	66.2	590.2	-35.1	625.3
Medium	3.08	4.26	1.18	37.5	14120.2	30.2	14090.0
Low	1.64	2.76	1.11	16.7	13329.5	595.3	12734.2
Overall	2.84	3.62	0.78	34.9	9293.6	196.8	9096.8

(b). National level estimations.

Altitude	Total rice area (ha)[a]	Area affected by MV	Increase in production (t)	Net returns ('000 Nu)
High	5302	3510	173	2194
Medium	10605	3972	4681	55968
Low	10605	1771	1970	22549
Overall	26512	9252	6824	80711

(Data source: Impact assessment survey 2002).

[a] Total rice area based on the Cadastral survey.

Appendix 25. Production with increased BMV adoption rates.

BMV adoption rate	Area affected	Increase in production	
		BMV over TV	BMV over OMV
5	795	1,265	1,002
10	1,591	2,529	2,004
15	2,386	3,794	3,006
25	3,977	6,323	5,011
30	4,772	7,588	6,013

(Source: Imapact assessment survey)

Note: Yield different of 1.59 (t/ha) and 1.26 (t/ha) for BMV over TV, and BMV over OMV, respectively and the national rice area for the high and medium altitude zones (15,907 ha) is based on the Cadastral survey.

Appendix 26. Difference in net returns for increased cost of production.

Production cost MV over TV (%)	Net returns	
	Nu/ha	National ('000)
17.2	9187.3	85005.3
30.0	9002.3	83293.6
50.2	8774.3	81184.0
75.1	8487.3	78528.6
100.1	8202.3	75891.6
149.9	7633.3	70627.0
200.1	7060.3	65325.3

(Data source: Impact assesment, 2002)

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