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RENEWABLE NATURAL RESOURCES RESEARCH CENTRE
BAJOTHANG, WANGDUEPHODRANG
"Walking the Extra Mile"

NATIONAL FIELD CROPS RESEARCH PROGRAM FOR 9TH FIVE YEAR PLAN

Program Report

Renewable Natural Resources Research Centre
Bajo, Wangduephodrang
Bhutan

October 2008

COUNCIL FOR RNR RESEARCH OF BHUTAN
Ministry of Agriculture
Royal Government of Bhutan

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Executive summary

The Field Crop Research Program encompasses research on staple cereals, oil crops and grain legumes. The main objectives of the program, as identified in the 10FYP document, were to develop technologies to optimize crop productivity and production and to support Dzongkhag extension in promoting the technologies. Research strategies employed to realize the objectives included introduction and adaptation of improved varieties and management methods for higher yields, reduction in yield losses (both field and storage) and conservation and use of indigenous crop genetic resources. A crop-wise review of the results and accomplished is provided in this paper.

In rice, five improved varieties for high and mid altitudes were released by RNRRCs.All released varieties have good yield potential. There are also a number of promising varieties in the pipeline. On crop management, research on developing improved agronomic, nutrient management, pest management and cropping system practices to enhance expression of a variety's potential was prioritized. The research output has been consolidated into packages of practices. Farmers have adopted many varieties and farming methods. Over 35% of rice areas are grown to HYVS with an adaptation rate of about 60%. The national rice output increased by 5000-10,000 tons per year, worth about Nu 60 million to Nu 121 million per year. Some challenges in rice research are better varieties for the low altitude zone, pest and diseases, nutrient management and availability of quality seeds.

Maize plays a crucial role in the household food security of rural population with 80% of the production consumed at home. The sale of by-products forms an input source of income. In the 9FYP, research on varieties for high altitude identified several promising ones such as Ganesh 2, Manakamana 3 and BTZT SYNT-4. For the low altitude, ZM 621 and Pop 44 C 10 show potential. In weed research, Metribuzin was tested and found effective against common weeds. Among diseases, Turcicum Leaf Blight (TLB) and Grey Leaf Spot (GLS) have been identified as major threats. To combat the disease, a breeding program has been started in the country. Maize germplasm known to have tolerance to TLB and GLS are being introduced and evaluated. An impact study on maize showed significant positive results of research and development. Maize HYVs are adopted by 60% of the households in 49% of the total maize area. The annual gain in production ranges from 12,000 to 14,000 tons, valued at 121 to 138 million Nu. About 7,000 tons of maize grains are estimated as surplus production.

Wheat ranks third after rice and maize among cereals. About 18% households cultivate wheat and it contributes about 2% to cereal production. There are three improved varieties recommended for rice-based system. At present not much research is being undertaken due to lack of access to improved germplasm and shortage of manpower. Among other minor cereals, millets, buckwheat and barley are important. These are grown as rainfed crops in mostly marginal areas.

The total area under these crops is about 21% and contribute about 10% to the total cereal production. In the 9FYP, detailed information on the farming practices and genetic resources of minor cereals have been generated and documented. At the research stations, a number of buckwheat, barley and millet varieties were introduced and developed. However, there is still a need to access more germplasm and information to strengthen research and development on monor crops.

The predominant oilcrops species in Bhutan are rapeseed-mustard. The other oilcrops grown in small areas are sunflower and niger. There are also some traditional oil-bearing tree species such as *yika, pangtse* and *shingtse*. The are and production of mustard has been steadily declining over the years mainly because of import of cheaper oils from India and elsewhere. There are several key issues in mustard production: inefficient methods of oil extraction, low yielding varieties, low use of inputs, sub-optimal cultivation practices, pest and diseases etc. In terms of research, it is limited at present due to lack of manpower and expertise.

Grain legumes (soybeans, mungbeans, pigeon pea, groundnut) are an important component of the Bhutanese farming systems and are grown in diverse land use systems. There are an estimated 16 species of legumes grown in the country. The most widely grown species across the country are Glycine max, Phaseolus vulgaris, Pisum sativum and Vigna spp. Data on the area and production of grain legumes are fragmented. It is estimated that 32,990 ha of land is under legumes cultivation. The total annual production of legumes would be around 14,000 tonnes. Although the Field Crops Research Program includes grain legumes as a component, there is very little research being undertaken in the research centres or in the farmers' fields. This is due to severe shortage of manpower to initiate and lead research on grain legumes.

1. Introduction

Field crops research program includes cereals (major cereals like rice, maize, wheat, and other cereals like barley, buckwheat and millets), oilseeds (rapeseed-mustard) and grain legumes (soybean, groundnut, mungbean). The program focuses on breeding, introduction and evaluation of improved genetic materials that are adaptable to local growing conditions, and the development of appropriate production technologies that can be adopted by the farmers. The research activities are executed both on-station and in the farmers' fields.

As a national mandate, RC Bajo also coordinates field crops research program with other research centres in the country as well as liaison with regional and international research centres for exchange of germplasm, expertise and technologies.

This report is a brief review of the results and accomplishments made by the National Field Crops Research program during the 9th Five Year Plan (2002-2007). It is a synthesized report of all the RNR RCs and their sub-centres pertaining to research and development on rice, maize, wheat, other (minor) cereals, oilcrops and grain legumes. The current review is done at a fairly broad level, not strictly limiting to the prescribed 5-year period or an exacting appraisal of the 9FYP document. Nevertheless, the report covers all the salient aspects of 9FYP and provides a sound basis for assessment of the research program at the national level. Within a commodity or crop, information is provided on the present area, production, varieties, management technologies, as well as issues and future challenges. The national level impact emanating from the research and development of major crops such as rice and maize is also highlighted.

2. Objectives of FCRP in 9FYP

As stated in the 9FYP document, the objectives of the field crops research program were:

- To identify, adapt or develop appropriate technologies for optimizing the productivity and production of field crops within the integrated RNR system.
- To identify production constraints and opportunities for developing appropriate technologies
- To develop/identify appropriate research methodologies appropriate to local conditions
- To support extension with appropriate technologies in the National Production Programs

3. Research strategies

The research strategies employed to achieve the stated objectives of the field crops research program were:

- Introduce, adapt and/or develop superior varieties of rice, maize, oilseeds, wheat and minor cereals and grain legumes specific to different altitude regimes and localised agro-environs.
- Adapt and evolve appropriate crop husbandry and management practices, including soil nutrients and water management, for optimising crop production processes.
- Identify or develop suitable management methods to minimise yield losses caused by weeds, diseases and insect pests.
- Conduct relevant research on post harvest and storage losses and recommend appropriate measures for yield reduction.
- Collect, characterise and evaluate indigenous crop genetic resources, in collaboration with NBC, for their conservation and utilisation in breeding and crop improvement programs.
- Study and identify potential pockets for itemised priority commodity research and development programs.

4. Review of results and accomplishments

4.1 Rice

4.1.1 Rice area and production

Rice is the staple food of the majority of the Bhutanese population. In the western and southern parts of Bhutan where it has been the traditional staple food, the per capita milled rice consumption ranges from 167 kg to 262 kg per annum. In areas where other crops have been the major calorie source, rice is now the preferred staple food. In urban areas, rice is also the preferred staple food. Domestic rice production does not meet the national requirement. The overall self-sufficiency level in domestic rice production is only about 50% (Rice CCA, 2006). The average rice import from 1995 to 2000 was about 33,000 t per year. Recently, the annual import amounts to more than 50,000 t. The demand for more rice is expected to increase over time. The major factors that contribute to this demand are the high population growth rate (2.5% per annum), increase in household income, and continuous migration to urban areas. The urban population, which represents 20% of the total population, is growing rapidly at a rate of at least 6% annually. Indeed, there is a need to increase domestic rice production.

In an impact assessment study conducted in 2002, the rice area decreased by around 9% mainly due to urbanization. However, production and average yield increased by at least 58% and 78%, respectively, during 1989 to 1997. This reflects the impact of research and development program of the country in the late 1970s up to the mid 1990s. The said period could be considered the green revolution era of Bhutan which focused on favorable environments (Javier, 2007). The national average yield of 2.77 t/ha based on 2004-05 data is 20% higher than the reported average of 2.30 t/ha during 1989-1997. This increase, however, was less than that obtained between 1989 and 1997. The impact of research and development efforts that focused mainly on favorable environments starts to show a diminishing return. Substantial gains may be achieved through innovative strategies for favorable environments and priority attention for less favorable ecosystems where improved technologies are needed.

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

Bhutan is divided into 20 dzongkhags or districts. The area grown to rice differ substantially among districts (Table 1). The total area grown to rice was 18,885 ha in 2004 to 25,295 ha in 2005, with a total rice production of 54,326 t and 67,607 t in the said years respectively. The average yield for the two years was 2.77 t/ha. Disregarding Bumthang which has a very small rice area, the district of Paro (t/ha) produced the highest yield (4.03 t/ha). It was followed by Wangdue, Punakha, Thimphu, Trashigang, Trashiyangtse, Mongar and Lhuntse, with yields of at least 3.00 t/ha. All districts are in the high and mid altitude zones. The low altitude districts comprise around 39% of the total rice area but contribute only 32% to the total rice production, indicating low productivity (Javier, 2007).

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

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

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

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

4.1.2 Review of research accomplishments

Varietal Improvement

Genetic diversity of varieties being cultivated is one of the factors that could stabilize crop production because of its buffering effect on the development of new races of pathogens or insect pest biotypes. Since 1988, the Variety Release Committee (VRC) has released 17 varieties, of which five, nine and two varieties are for high, mid and low altitude lowland environments, respectively. Eleven of 17 varieties originated from Japan, Nepal, China, Korea, India and IRRI (Table 2). One introduction from Nepal named Chommrong Dhan (released in Nepal in 1991) is a selection from Ghandruk, a Nepalese landrace. Six of 17 varieties released were developed by Bhutanese plant breeders, reflecting the RNRRCs capability to generate their own materials using limited resources.

Table 2: Varieties released in Bhutan for different agro-ecological zones from 1988 to 2006 and their pedigrees.

Release name	Year of release	Designation	Pedigree	Origin
High altitude				
No 11	1989	Takanenishiki	-	Japan
Khangma Maap	1999	Chommrong Dhan	A selection from landrace Ghandruk	Nepal
Yusi Ray Maap	2002	IR62746-B-4-8-1-1	Suweon 359//IR41996-118-2-3 /Thimpu Maap	Bhutan
Yusi Ray Kaap	2002	IR66068-B-B-31-2-1	YR3825-11-3-2-3-1 YR3825-11-3-2-1/Barkat	Bhutan
Jakar Rey Naab	2006	Paro China	-	China
Mid altitude				
IR64	1988	IR64	IR5657-33-2-1/IR2061-465-1-5-5	IRRI
IR20913	1989	IR20913-B-60	IR7149-51-1-3/IR36//Paro White	IRRI
Milyang 54	1989	Gayabyeo	Milyang 21/IR 32//Milyang 23 /Milyang 30	Korea
Barkat	1992	Barkat (K78-13)	Shinei/China 971	India
Bajo Maap 1	1999	CARD21-10-1-1-3-2-1	Local Maap/IR64	Bhutan
Bajo Maap 2	1999	CARD21-14-1-1-3-2-1B	Local Maap/IR64	Bhutan
Bajo Kaap 1	1999	IR61331-2-148-B	IR41996-118-2-1-3/Paro Maap	Bhutan
Bajo Kaap 2	1999	IR61328-1-136-2-1-2-3	IR41996-118-2-1-3?Bja Naab	Bhutan
Wengkhar Rey Kaap 2	2002	Khumal 2 (NR168)	Jarneli/Kn-LD-361-DLK-2-8	Nepal

Wengkhar Rey Kaap 6	2006	Khumal 6 (NR10172-2B-12-4-1-3-2)	IR 13146-45-2-3/IR17492-18-6-1-1-3-3	Nepal
Low altitude				
BR 153	1989	BR153-2B-10-1-3	IR578-172-2-2/BR1-2-B-19	Bangla-desh
BW 293	1990	BW 293-2	IR2070-586/BG400-1	Sri Lanka

All released varieties have high yield potentials (Table 3). There is a good range for growth duration. Intermediate height is a desirable attribute and BW 293 (dwarf type) is not so popular. Varieties with red pericarp command a good price. Some releases have this characteristic.

Table 3: Characteristics of varieties released for different agroecological zones in Bhutan from 1988 to 2006.

Release Name	Yield Potential (t/ha)	Growth Duration (days)	Plant Height (cm)	Grain Color
High altitude				
No 11	5-6	160	90	white
Khangma Maap	4-5	120-130	90-100	red
Yusi Ray Maap	7-8	-	100-112	red
Yusi Ray Kaap	7-8	-	90-100	white
Jakar Rey Naab	4-5	-	90-100	white
Mid altitude				
IR64	6-8	-	80-90	white
IR20913	4-6	130-140	100	white
Milyang 54	6-8	140-145	95	white
Barkat	4-5	155	90-95	white
Bajo Maap 1	6-8	150-155	100-105	red
Bajo Maap 2	6-8	145	100-110	red
Bajo Kaap 1	7-8	145-155	95-105	white
Bajo Kaap 2	7-8	150-155	90-100	white
Wengkhar Rey Kaap 2	4-5	-	100-105	white
Wengkhar Rey Kaap 6	4-6	-	105-110	white
Low altitude				
BR 153	4-5	140-150	100-110	white
BW 293	4-5	140-150	75-85	white

Promising varieties in the pipeline

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

Table 4:Yields (t/ha) of promising test entries and check varieties for mid altitude environment in researcher- and farmer-managed trials, 2000-06.

Environment[1]	Data Set I			Data Set 2	
	Guojing 4	SPR87036-7-1-1-2	Check[2]	B2983B-SR853-2-4	Check[2]
2000-01 Observational Nursery	6.90	7.00	4.85	5.90	4.85
2001-02 Initial Evaluation Trial	8.38	7.94	5.35	7.12	5.35
2002-03 Initial Evaluation Trial	-	-	-	7.24	4.59
2002-03 Advanced Evaluation Trial	7.45	7.36	6.74	-	-
2003-04 Advanced Evaluation Trial	8.40	7.87	6.04	7.84	6.04
2004-05 OFAT Nisho, Wangdue	5.94	4.91	4.60	5.53	4.60
2004-05 OFAT Phangyl, Wangdue	3.11	4.33	4.77	4.55	4.77
2004-05 OFAT Tewang, Punakha	6.08	7.39	4.28	6.06	4.28
2004-05 OFAT Kabji, Punakha	5.30	5.50	4.10	6.00	4.10
2005-06 OFAT Ruchika, Wangdue	6.28	7.18	4.77	8.85	4.77
2005-06 OFAT Thangu, Wangdue	9.50	9.50	8.40	8.40	8.40
2005-06 OFAT Maphina, Wangdue	5.23	4.97	4.37	5.73	4.37
2005-06 OFAT Zomi, Punakha	6.79	7.27	5.80	7.27	5.80
2005-06 OFAT Tewang, Punakha	6.53	6.75	6.45	6.07	6.45
2005-06 OFAT Kabji, Punakha	5.98	5.75	4.00	5.17	4.00
2005-06 PVS Thangu, Wangdue	9.50	9.50	8.40	8.40	8.40
Mean	6.76	6.88	5.53	6.68	5.38
% Yield Advantage over the check	22.3	24.5	-	24.0	-

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

The yield performance of three potential varieties for the low altitude zone is given in Table 5. HB242 has a yield of 4.36 t/ha over nine environments and a yield advantage of 28.4% over the check. Its yield is higher than and at par with the check in eight and one environment, respectively. IR72102-3-115-1-3-2, with a mean yield of 4.53 t/ha over ten testing sites, shows a 41.4% yield advantage over the check. Its yield is higher and lower than the check in nine and one environment, respectively. TOX3098-2-2-1-2-1 has a mean yield of 5.32 t/ha across nine environments and a yield advantage of 53.6%. It outperforms the check in all trials. All test entries outperformed BR153 in environments where it was the check (Javier, 2007).

Table 5:Yields (t/ha) of promising test entries[1] and check varieties for low altitude environment in researcher and farmer-managed trials[2], 2002-05.

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

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

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

All materials have been developed in different national and international research centers. Guojing 4 was developed in China; SPR87036-7-1-1-2 in Thailand, B2983B-SR853-2-4 in Indonesia, and HB242 in Taiwan, IR72102-3-115-1-3-2 is in IRRI and TOX3098-2-2-1-2-1 in Nigeria-based International Institute for Tropical Agriculture. The release of these promising selections will not only increase the varietal options for farmers' use and rice productivity but will also add up to the genetic diversify in farmers' fields.

Adoption of released varieties: a national perspective

Varieties grown in Bhutan can be classified into released and Bhutanese traditional varieties. Sixteen releases are modern varieties, being products of hybridization and selection. One released variety (Khangma Maap) is a selection from a Nepalese landrace and thus, an improved traditional variety. Bhutanese farmers often grow more than one variety in their fields which could be different traditional varieties only, released varieties only and combination of the two varietal groups. In the impact assessment study based on 2002 survey involving 248 households from high, mid and low altitude areas of seven main rice producing dzongkhags, the adoption rates of the fifteen varieties released from 1988 to 2002 was examined. Households growing released varieties only and combination of released and traditional varieties were considered as adopters. Salient findings at the household level analysis are as follows:

- The adoption rate of released varieties across zones was around 60%.

- The highest adoption rate of released varieties was in the high altitude zone (77%) followed by the mid altitude (59%) and low altitude (32%) zones. Some 56% of the households across zones grew released varieties only and combination of released and traditional varieties.
- The frequencies of households growing released varieties only and combination of released and traditional varieties were 77% in the high altitude zone, 58% in the mid altitude and 32% in the low altitude (56 % in the 2003 survey report).

Varietal adoption in terms of area planted was also examined in the 2002 survey. The area grown with released varieties is about 35%. Partitioning of the data at the altitude level indicated 66%, 38% and 17% adoption rates in high, mid and low altitude zones, respectively. Further partitioning at the variety level revealed that most varieties released/selected under a particular altitude zone were planted not only in their target altitude zone but also in other altitudes (Table 6). This reflects the spill-over effect of research efforts in a given altitude zone in other environments. IR 64 had the widest adaptation having been grown in all altitude zones. In contrast, BR 153 which was selected under low altitude was only grown under that environment, indicating narrow adaptation. Yusi Ray Maap and Wengkhar Ray Kaap 2 were released at the time the survey was conducted but had been included in on-farm trials earlier. They were being cultivated in their selection environments but may find their own niches in other environments over time.

Table 6: Percent area under each variety released from 1988 to 2002 in places growing improved varieties situated in different altitudes

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

Data source: 2002 survey report in economic impact assessment.

Old releases such as Barkat (1992), BW 293 (1990) and Milyang 54 (1989) were not cited by farmers in the survey which may mean that they were no longer cultivated (short varietal life span) or grown only in limited areas (site-specific adaptation). On the contrary, IR 64, BR 153 and IR20913 have a long varietal life span, having been grown by farmers since the late 1980s until now. Yusi Ray Kaap which was released in 2002 was also not mentioned by farmers in the 2002 survey. It may take sometime before one can make a judgment on its usefulness and longevity.

The most widely grown modern variety is BR 153 in the low altitude environments. Its higher yield potential and stability, shorter growth duration and better resistance to pest diseases than the local varieties are the major attributes for its adoption. Its negative traits are poor taste, low milling recovery with many broken grains, and short straw. Straw yield is very important since it is used as animal feed and sometimes as roof for houses. Farmers mention that BR 153 straw is not palatable for cows and rots easily. A family with many members ignores these negative traits because of its yield potential and ability to escape drought because of its short growth duration. It is often mentioned that the poor quality of modern varieties is still better than that of rice imported from India that they buy during lean months. IR 64, Bajo Kaap 1 and Bajo Kaap 2 are not adapted in the unfavorable areas of the southern belt since they have been selected for mid altitude zones.

PIcture 1: A good stand of BR 153 is observed in a farmer's field at Chhuzargang.

Crop management and post harvest technologies

Research efforts along the development of improved agronomic, nutrient management, pest management, post harvest and cropping systems practices have focused on how to enhance the expression of a variety's yield potential, taking into consideration farmers' available resources and capacity to purchase inputs (Javier, 2007). Research outputs are consolidated into packages of recommendations and options for increasing crop productivity. Some highlights are:

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

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

- Management practices that could help in controlling blast problem have been developed.
- Effect of various planting methods and time of planting on yield have been conducted.
- Cultural management practices and herbicides that control a new weed problem, locally called *sochum* (*Potamogeton distinctus*), have been identified.
- Polytunnel method of raising seedlings during cold months has been proven effective and can now be tried in the first crop of a double cropping system and in rice production at very high elevation (Bumthang).
- The pre-rice green manuring crop, Dhaincha (*Sesbania aculeate*) has been re-introduced in the low altitude rice growing areas.
- Chinese milk vetch (astragalus sinicus) has been identified as suitable green manure crop for elevation above 1,300 m for winter crop.
- Grain moth (*Sitotroga cerealella*) and grain weevil (*Sitophilus oryzae*) have been confirmed as the major seed storage problems of rice farmers.
- Sampling procedures and methods for measuring field crops yields have been developed for taking crop cuts.

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

The use of chemical fertilizers and herbicides is limited. The constraints to adoption given by the farmers are the following:

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

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

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

Socio-economics and policy

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

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

4.1.3 Constraints in rice production

Varietal constraints

In the southern foothills, only BR 153 has been adopted by a reasonable number of households. Farmers have tried growing varieties released for other environments with no comparable yield advantage with BR 153. The big challenge is to provide farmers with a set of genetically diverse varieties that are adapted to local environments and possess desirable attributes such as high level of tolerance to drought. Other environments such as the humid subtropics and high altitudes also require better variety options.

Biotic constraints

Weeds, diseases and insects pests impinge on the growth and development of plants. Farmers report that yield could be reduced by as high as 50% each by weeds and disease infestation and by 24% by insect pests. Finding varieties that tolerate such stresses or developing affordable solutions to the problem remain a challenge.

Soil fertility constraints

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

Irrigation constraints

There are rainfed lowland areas that may obtain supplementary irrigation from perennial canals/springs/streams and rainfall activated sources. These water channels are being tapped by farmers, but a major problem is the erratic supply of water in the existing discharge systems in terms of volume, discharge rate and continuity of supply. Some of the water channels are very old and need reinforcement while others are damaged by floods/landslides and need repair. It is a challenge to provide engineering services to improve the existing water discharge systems.

Vertebrate pest problems

The natural habitats of elephants, monkey, wild boar and rodents are just a short distance away from farm lands. These vertebrates often roam around rice fields and cause crop damage. The vertebrate pests are responsible for 47% reduction in crop yield (Javier, 2007). Elephants come in herd and can damage 80% to 100% of a standing crop, leaving nothing to harvest. Around 38% of the labor employed in rice production is focused on crop guarding. It is therefore a big challenge to find ways to protect both wild life that destroys agricultural crops and the livelihood of the people dependent on food production.

Post harvest constraints
Sun drying is the only system available to reduce the moisture content of the seed to about 14% after harvesting. Extended late showers may take place after harvest and grain quality and milling recovery could be severely affected. Seed storage pests are reported to reduce the total produce to about 13%. Grain moths and weevil are the major concerns of the farmers. Studies on how to control storage insect pests are therefore needed. One factor that may have been contributing to low milling recovery is the old rice mills in villages. There is a need to assess the rice mills if they are contributing to the yield loss due to low total and head rice recoveries. Rice mills with rubber rollers to remove the husks are known to produce less broken grains.

Labor constraints
Non-mechanized rice cultivation is a labour-intensive farming system. A major solution to the labour shortage is a certain degree of farm mechanization. At present, only 4% the households have their own farm machine. Development of cheap and efficient farm machinery and small farm tools that will reduce drudgery in rice cultivation is a major challenge.

Seed constraints
A land race is expected to exhibit uneven stand because it is composed of genetically diverse homozygous genotypes. In contrast, a released variety should be homogeneous since it is a pure line. Uniformity in crop stand of released varieties can be observed in the research stations. However, released varieties

grown by farmers exhibit non-uniformity in height and growth duration, indicating genetic impurity or mixture. Yield is reduced because of uneven competitive ability for light between tall and shorter plants. The quantity and quality of the harvest is reduced when immature and mature grains are harvested together.

4.1.4 Research Publications

List of publications made in Field crops program

Sl	**Title**	**Year of publication**
1	An Economic Impact Assessment of Rice Research Program in Bhutan	2004
2	Recommended practices of direct seeding in Rice	2004
3	Pre- Rice green manure	2004
4	Rice double cropping in dry subtropical zone	2004
5	Mustard cultivation in wetland production system	2004
6	Technical guidelines for measuring crop yields in Field crops	2004
7	Rice cultivation in medium altitude	2005
8	Rice cultivation in low altitude	2005
0	Rice ratooning	2005
10	Recommended rice seeding production practices	2005
11	Recommended practices for rice production in warm temperate zone (high altitude)	2005
12	Wheat cultivation in wetland production system	2005
13	Adoption and Impact of improved Maize technology in Bhutan	2006
14	A review of rice research in Bhutan with emphasis on rainfed rice	2008
15	Annual Reports	2002-2007

4.2 Maize

Maize is a major food crop of the country and is cultivated by 69% of the rural households for subsistence (RNR 2000). It is cultivated across the country and it ranks first in terms of the area and production of food crops. Although the extent of cultivation varies widely, maize is cultivated in all the 20 Dzongkhags. The RNR Statistics 2000 show that out of the 202 Geogs a total of 189 Geogs produce maize. Most of the maize is cultivated in the drylands, followed by *tseri* and to a small extent in wetland especially in the south. The cultivation ranges from less than 300 m upto 3000 m owing to its versatile capacity to adapt to different environments. Maize is also cultivated as a second crop in the lower altitudes and is estimated to cover about 15% of the total area under maize.

4.2.1 Food Security and Importance of Maize

Maize plays a critical role in the household food security as it is a staple food. It is estimated that 80% of the total production is consumed at the household level by the farmers; this is valued at Nu. 353 million annually. About 6% of the total production is sold which serves as an important source of household income. The processed maize products are also important source of household income. Another very important role of maize in food security is that it serves as an important source of feed for household livestock. The latter in turn are the primary source of household cash income and manure for crops. Maize combines very well with other crops like potatoes, legumes and vegetables and allows high land use intensity through intercropping. Despite the change in food habits and preference for rice, the survey indicated that still 24% of the households prefer maize as their first staple. Although, the consumption of sole *kharang* has gone down but maize still continues to significantly substantiate the food needs as it is mixed with rice in various ratios. Although it is generally perceived that the country is self sufficient in maize, Maize Impact Assessment study has indicated that 32% of the surveyed households still do not have sufficient maize to meet their annual household requirement. The percentage of household who have not adopted improved technologies had higher (57%) maize shortage as compared to those growing improved varieties (43%). Despite the government's existing subsidies on inputs, free promotional programs, and capacity development of research, extension and farmers to support the increase in production of maize, there is still sub optimal production in some Dzongkhags.

Recognizing the role of maize in the household food security, maize research program was accorded a high priority.

4.2.2 Maize Area and Production

The maize production environment in the country is broadly categorized into three zones mainly based on the altitude. The three production zones are, Sub-tropical maize production zone I (<1200 m asl) or low altitudes; Sub-tropical maize production zone II (1200 -1800m asl) or mid altitudes; and the Highland maize production zone (>1800 m asl).

The national area under maize is estimated at 76,938 acres with a total production of 77,298 Mt (RNR Stats, 2000). According to the Agriculture statistics 2004, the estimated maize area is 53,938 acres accounting for the total production of 90,566 Mt. There is a decrease in the area cultivated but an increase in the production. Farmers assign the damage by wild animals as the main reason for the decrease in maize area especially in the far flung areas. Another important reason assigned by the farmers for decline in area is the legislation on *tseri* cultivation. There is an existing forestry rule to revert the agricultural farmlands left fallow for over 12 years and any farmland with significant growth of trees to forest. Enforcement of this rule recently led to the reverting of over 1100 acres of agricultural land in 17 Dzongkhags to the government as forest land (MoA, 2006).

Although maize is grown in all the Dzongkhags but the extent of cultivation varies. According to the Agriculture Statistics 2004, there are 13 Dzongkhags which account for 99% of the total maize area and production.

Table 7: Region and Dzongkhag wise distribution of maize area and production

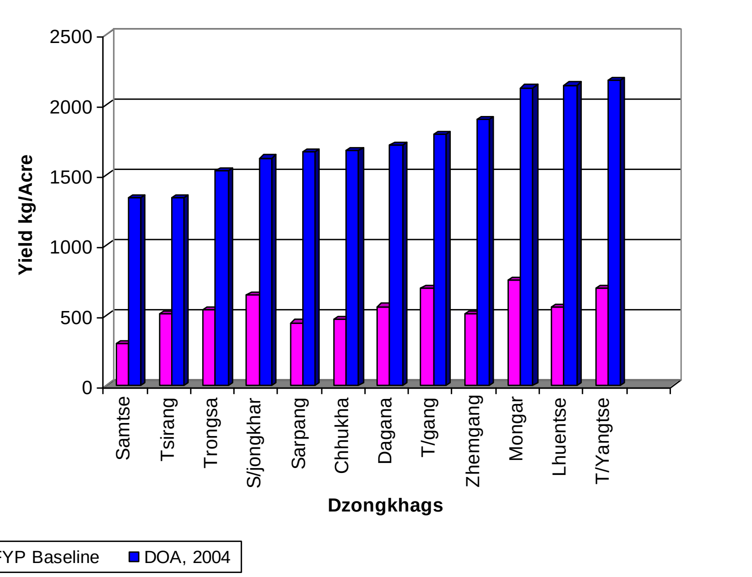
Region/ Dzongkhag	Area % of total	Production % of total	Yield (t/ha)
Western	**19.60**	**16.09**	**3.40**
Thimphu	0.03	0.02	2.33
Paro	0.02	0.00	0.82
Ha	0.21	0.20	3.99
Chhukha	2.40	2.39	4.13
Samtse	16.94	13.47	3.30
West-Central	**19.74**	**18.52**	**4.04**
Punakha	0.27	0.33	4.97
Wangdue	0.21	0.24	4.76
Tsirang	7.61	6.06	3.31
Dagana	11.65	11.89	4.23
East-Central	**15.41**	**15.78**	**4.24**
Trongsa	1.67	1.52	3.77
Zhemgang	4.57	5.16	4.68
Sarpang	9.17	9.10	4.11

Eastern	**45.25**	**49.62**	**4.50**
Mongar	11.34	14.32	5.24
Lhuentse	4.28	5.45	5.28
Trashi Yangtse	2.25	2.91	5.37
Trashigang	15.29	16.30	4.42
Pemagatshel	2.58	1.45	2.32
Samdrupjongkhar	9.51	9.19	4.01
Total	**100.00**	**100.00**	**4.15**

Among the, thirteen Dzongkhags, there are nine Dzongkhags that have more than 4% of the national maize area and each of these individual Dzongkhags contribute greater than 5% of the production. The highest proportion of production is from Trashigang (16%) followed by Mongar (14%), Samtse (13%), Dagana (12%), Samdrupjongkhar and Sarpang (9%) each, Tsirang (6%) and, Lhuentse and Zhemgang 5% each (Table 7). Besides these nine Dzongkhags, maize is also very important in Pemagatshel, Chukha and Trashiyangtsi Dzongkhags.

Comparison of the yield between the 9FYP baseline data and the Agriculture Statistics 2004 shows a constant increase in yield (Fig 1) in all the 13 main maize producing Dzongkhags.

Fig. 1 Maize Yield of 13 main Maize growing Dzongkhags



Maize productivity has significantly increased due to the increase in adoption of improved technologies. The yield per unit area has increased from 2.52 t/ha in 2000 to 4.15 t/ha in 2004. It has been recorded that 60% of households have adopted improved varieties covering 48.5% of the total area. About 41.3% of the household planting improved varieties also use fertilizers in maize production.

The national maize impact assessment survey estimated the yield of improved varieties to be 2.47 t/ha as against 1.17 t/ha of the traditional varieties with a yield difference of 110%. The estimated yield in this survey is much lower compared to the national average of 4.15 t/ha (DOA 2004). The possible explanation for this large variation could be that the survey data is recalled information and farmers often tend to report lower yields for various reasons. Farmers' reported yields are based on total harvest from the whole farm while the crop cut estimates are normally based on small area. Although there is an healthy trend in the yield, there is a need to revisit the yield estimation procedures presently undertaken by the Extension Agents to develop more realistic baseline for 10FYP.

4.2.3 Review of research accomplishments

High altitude maize improvement

In the past, maize variety development research focused more on the selection of varieties for the Sub-tropical maize production zone II (1200 -1800m asl) or mid altitudes. The released varieties are not suitable for the highland maize production zone (>1800 m asl) which has 20% of the maize area. There was an acute need for development of suitable varieties for the high altitude (>1800 m asl). Accordingly, over 400 lines of maize germplasm for high altitudes were introduced from CIMMYT Nepal and evaluated through on station and on-farm trials.

Three new lines were advanced to researcher managed on-farm trials at two locations (Table 8). The yield performance was good but all the varieties displayed poor resistance to Gray Leaf Spot and Turcicum Leaf Blight diseases.

Table 8: Performance of three new varieties in two Geogs

	Drepong	Chaskar	Mean Yield t/ha
Varieties	Yield t/ha		
BTZT SYNT -4	5.95	2.86	4.40
Manakamana 3	7.44	4.17	5.80
Ganesh 2	5.65	2.38	4.02
Khangma Ashom 1	5.36	2.38	3.87

From among the above three varieties, Ganesh 2 with yellow flint which performed consistently better in the past was also tested nationwide in the Geogs representing the high altitude areas through the nationally coordinated trial. The yield performance of the variety was quite good but unfortunately the variety was found to be highly susceptible to the Gray Leaf Spot and Turcicum leaf Blight diseases. Now more materials resistant to Gray Leaf Spot have been introduced and the thrust to select suitable varieties for the high altitude zone will continue.

Mid/low altitude maize improvement

The maize variety improvement research under this project focused on identification of extra early varieties for maize double cropping and full season white flint varieties for the low altitude areas. Two new lines Arun 2 and Ganesh 2 will be advanced to the farmers field trial in the coming season to see their feasibility for second season in maize double cropping areas. For the low altitudes, sufficient seed increase of two new varieties ZM 621 and Pop 44 C10 have been done and they will be advanced to farmer's field trial in the next season.

Agronomic studies (Weed management)

Maize is one crop that can be seriously affected by weed competition especially at the early growth stages. Four different weed species are most common and noxious in maize (Table 9). Farmers say that weeding is the most labour demanding operation in maize cultivation and could account over 50% of the production cost. At present weed control methods are entirely manual and the labor requirement is high. Maize is invariably intercropped with different crops which makes the use of chemicals difficult. The most critical period of weed competition in maize is two weeks after sowing to about six weeks. It is recommended for manual control of weed at least two hand weeding should be done. The first weeding should be done 20-25 days after crop emergence and the second weeding 40-45 days or 3-4 weeks after the first weeding.

Table 9: Most common weeds that infest maize

Scientific name	**Dzongkha**	**Sharchogpa**	**Lhotshamkha**
Persicaria runcinata	chumchum/helepsi/ shido	ganghuma/gangchimin	ratnaulo
Persicaria nepalensis	helepsi/shido	metoshim/ gangchuma	ratnaulo
Fagopyrum dibotrys	geray yuma	khala/themnang	titay phaphar
Galingsona parviflora	jagayouma	yurungpa	udasay

The use of chemicals for weed control was tested and Metribuzin 70% W.P has been found to be quiet effective for chemical control of weeds in maize. Metribuzin 70% W.P is applied as pre-emergence against annual grasses and different broad leaf weeds. Metribuzin can be used for weed control in sole maize and maize-potato intercropping. It controls most weeds but only weakens *Persicaria runcinata*, *Persicaria nepalensis* and *Fagopyrum dibotrys*. It is available with the National Plant Protection Centre. Farmers have experiences that Metribuzin 70% W.P is effective on most weeds in maize. It drastically weakens the most noxious weed Gangchimin and Themnang and reduces labour required for weeding by almost 50%.

Persicaria runcinata

Persicaria nepalensis

Fagopyrum dibotrys

Galingsona parviflora

Soil fertility and conservation

In the absence of the required research capacity at Wengkhar, most of the activities under this project were conducted under the leadership of the National Soils Service Centre (NSSC), Semtokha. The long term activities conducted under this project included the monitoring of soil fertility status under the maize based farming system, capacity building of the Extension Agents on soil fertility management through in service training and distribution of the Integrated Plant Nutrient Management manual to the Extension Agents.

Storage and post harvest loses

The Overall post-harvest loss was reported at 20% during the farm survey and it is reported to be 26% higher among the farmers growing traditional varieties. To address this issue, maize research program focused more on selecting varieties with good husk cover, training of Extension Agents and farmers on the management of the crop, time of harvesting and management of appropriate moisture content of maize. The Department of Agriculture has given high priority to address these issues through supply of suitable storage silos.

Disease and insect pests

Under this project, the thrust was placed on the identification of the disease, development of resistant varieties and control measures. Since 2006, the damaging effect of the of turcicum leaf blight (TLB), caused by the fungus *Exserohilum (syn. Helminthosporium) turcicum* was noticed particularly in areas over 1500 m asl. To assist the maize program to formulate strategic plan of action for disease control, assistance of a technical expert was sought. With the technical input, it was found that Gray Leaf Spot, another disease caused by the fungus *Cercospora zeae maydis* was causing damaging effects. The total numbers of household affected by the disease was is 3835 and the total area affected was 4711.76 acres. A total of 2987 households lost more than 50% of their production.

Severe incidences of Gray Leaf Spot was observed at elevations nearly and above 1800m asl. At the elevations 1700-1800m asl both Gray Leaf Spot and Turcicum Leaf Blight were prevalent. Below 1700 m asl, Turcicum Leaf blight was more prevalent, but with incidences of lesser economic significance. To combat the disease a long term breeding program to select yellow endosperm maize tolerant to the disease has been started with support of CIMMYT. Cercospora-tolerant maize germplasm available from CIMMYT have been introduced and selection started. For the short term a new systematic fungicide has also been recommended. Training and awareness campaign on the disease has been started in collaboration with the Department of Agriculture. Training materials and five different posters on the disease have been developed for trainings of farmers and the Extension Agents. Training of Extension Agents on maize production and disease management in the different Dzongkhags has also been started.

In addition to the above project, the maize program also initiated work on variety maintenance, seed production, community based seed production and conservation.

Variety maintenance and seed production

In the beginning of the 9FYP a serious concern was raised on maize seed degeneration. Seed degeneration or varietal contamination was due to out-crossing in maize. The entire area under maize is planted to the open pollinated varieties (OPVs) and Bhutanese farmers cultivate more than one variety to meet their specific needs. Normally farmers save seed from their previous harvest. As maize is a highly cross-pollinated crop there is a large difference in genetic composition of the successive generations. New genetic combinations are continuously formed in the farmer's field resulting in the variation of plant height, husk cover, grain colour kernel types etc. Good seed production would require isolation which can be achieved either through time or by distance. These are however not very practical under farmer's condition as farmers have limited land holding and in the higher altitude delayed planting affects the sowing of the winter crop after maize.

To address this problem, maintenance breeding of released varieties was started at Lingmethang. Breeder seeds were obtained from CIMMYT and a rigorous maintenance breeding program was started at Lingmethang by adopting Isolated Bulk Converted into half-sib crossing block.

A simple manual for maintenance and seed production of open pollinated varieties was developed and widely circulated to the stakeholders. Over 300 farmers and 100 Extension Agents were trained nationwide trained on maize seed selection techniques. A small scale seed replacement in key areas was also started.

Community Based Seed Production

One of the primary inputs for a sustainable maize production is the supply of quality seed. Under farmers conditions it is technically difficult to produce seed and maintain varietal purity of the maize crop. Good maize production therefore requires frequent seed replacement. Availability of quality seed has been a perennial problem mainly owing to the cross pollinated nature of the crop and maize cultivation practice causing complexities in adopting necessary precautionary measures for quality assurances.

To address this issue, RNRRC Wengkhar successfully tested the concept of Community Based Seed Production (CBSP). CBSP basically entails the organisation of a small community into a seed producer group which with the support of research and extension produces and markets maize seed. An appropriate site preferably secluded to avoid rampant outcrossing is important. The CBSP group will be asked to grow same variety and follow all technical requirements and there by ensure the seed quality. Farmers can benefit in two ways. First, their production will increase a result of good seed and secondly they can earn cash through the sale of seed.

CBSP was started at Martshala Geog in collaboration with the Dzongkhag Extension Services with seven farmers. The group was provided with all the inputs and basic seed of maize variety Yangtsipa. All the technical support required were provided by RNRRC and the Geog extension Staff. Farmers expressed that they became aware on the advantage of producing seed in the geog. They also liked the improved variety and showed their keen interest to continue producing seed of the improved variety. More farmers were keen to join the CBSP group. A total of 438 Kgs of seeds were selected and brought to the Extension Centre. This seed was purchased with the fund provided by the DoA and again handed back to the Extension Agents for further distribution. The quantity produced was quite low because a severe drought spell in the beginning affected germination and furthermore the selection for seed was quite stringent.

Participatory conservation, development and utilization of maize

Focus was also given to the On farm conservation, development and utilization of maize in collaboration with National Biodiversity Centre (NBC) at the three sites in Khalling, Kanglung and Dremetse Geogs. Three farmer's groups comprising of 28 farmers have been formed. The activities in the three sites included the conservation of traditional maize varieties, product development and marketing of maize products, participatory rehabilitation and assessment of the local maize variety through ear to row selection and bulking the best lines.

Conservation will be effective and meaningful if the commodity being conserved is useful to the farmers. One of the main challenges in maize is the utilization as many farmers prefer rice. To address the utilization issue three *tengma* making machines were supplied to the farmers' group at the three sites. With this the farmers have been able to convert their local maize into *tengma* and sell. This has also become an important source of income for the farmers and they have started group savings.

Production Economics

The gross national income from maize is estimated at Nu 729 with a total value added of Nu 376 million. The Value Added represents the income earned from the sale of a commodity minus the cost of intermediate inputs. From the total value added 48% is accounted for farmer's income, 24% as salaries of hired workers and 28% as home processing. The economic productivity of the maize farm is valued at Nu.6551 with an average economic profit of Nu. 4836 per farm. The farm labour productivity is quite low and is estimated to be 28/kg of maize/day. This is mainly because most of the maize cultivation is done manually as the scope of mechanization is limited. The economic return of farm labour/man days is worth Nu.115 which is 13% higher than the daily wage of Nu.100 that one would earn by working off farm. The economic cost of production of maize is Nu 5.3/kg and the financial cost of production is Nu 3.54/kg. The maize chain is a good source of employment with an annual employment mobilization of 38, 639 people. The maize chain is also an important source of on-farm employment and supports 37,099 micro enterprises *(for details refer to the Maize Commodity Chain Study, 2006).*

Technology Impacts

In the middle of the 9FYP, a major study was launched to assess the impact of maize technologies. This study revealed significant positive impact from the adoption of improved maize technologies. The technologies developed so far are increasingly adopted, and as these technologies are refined and disseminated further adoption is likely. The major highlights of the impact of maize technologies are as follows:

- The estimated gain in production for 2004 that could be directly attributed to the maize program is in the range of 12,000 to 14,000 tons. The value of this increased production is Nu 121 to 138 millions at the price of Nu 10,000 per ton. Over 85% of the increased production originated from production Zone II.
- Approximately 8% of the total production is estimated to be surplus production (over 7000 tons). Surplus originated mostly from the modern variety adopter households (79%).
- The adoption of improved maize varieties (IMVs) underpinned this increase in production. These IMVs are adopted by 60% of the surveyed households and planted to 49% of the total maize area. Approximately 60% of the second maize crop area is also planted to IMVs.
- Yangtsipa, the first IMV released, is the most popular variety. It is planted to over 90% of the area cultivated to IMVs in both altitude Zones. The main reasons for adoption of the variety were its high yield potential and resistance to lodging.
- Improved crop management practices such as seed selection, intercropping with maize, double weeding and application of inorganic fertilizers are increasingly adopted for IMV and traditional maize varieties (TMV) cultivations. More than 41% of the households applied some inorganic fertilizers in IMVs with more than 37% applied during top dressing as recommended. Substantially higher amount of farm yard manure is applied to IMVs as compared to TMVs. In the Zone II, almost

three times the level of farm yard manure is applied in the cultivation of IMVs as compared to TMVs.

- The IMVs out yielded the traditional varieties (TMVs) in both the production zones. Overall, the yield advantage of IMVs over TMVs is 110%. The percentage gain in yield translated into absolute increases of 1300 kg per ha.
- Farmers who grew IMVs had increased their net incomes by over Nu 11,400 per ha, an increase by 123% when compared to the cultivation of TMVs. At the national level, this gain translated to net return in the range of Nu 105 to 121 million. Given the yield advantage, cultivation of IMVs was found to be profitable even under the assumption of its market price being 50% lower than the current value (e.g. 5 Nu/Kg).
- The adopter households obtained over Nu 5,700 cash income from maize. This earning was almost 100% higher than as compared to non-adopter. This higher cash income is attributable to increased production that enabled the subsistence farmers to increase their marketed quantity.
- Overall 35% of the surveyed households had maize surplus. Among the adopters, almost 80% had surplus as compared to 20% among the non-adopters. The quantity of surplus among the adopters averaged at approximately 350 kg, a difference of 14% relative to non-adopter households.

4.2.4 Constraints and issues in maize

The following are some of the issues in maize which can serve as the areas of intervention for maize research program in the 10 FYP:

- Crop losses to wild animals - Every year about 11% of the maize is lost to wild animals (BNFSSP, 2006). The major wild pests that damage maize are wild pigs, monkeys, bear, porcupines, rodents and birds.

- Soil fertility and drought- The most important means of fertilization of maize crop is through the use of Farm Yard Manure (FYM) or solely through tethering cattle. There is a need to explore and identify suitable soil fertility management options to further enhance the productivity of maize production system. Maize crop is entirely grown as rainfed and farmers watch for rain to sow their crops. At present there are no suitable verities that can tolerate moisture stresses.

- Disease: Gray Leaf Spot (*Cercospora zeae- maydis*), Turcicum Leaf Blight (*Exserohilum turcicum)* and different types of Ear rots are emerging as a major disease especially in the higher elevations. There are no resistant varieties against these diseases

- Lack of a suitable marketing mechanism **-** Approximately 8% of the total production is estimated to be surplus. Production in small volumes, high price demand by farmers and the need to collect from widely scattered areas hinders smooth marketing of maize. At present there is no place where farmers can take and sell their grains readily like the FCB auction yards where vegetables and other cash crops are sold. There also an urgent need to try and establish small scale maize using enterprises.

- Poor Processing technology- Home processing of maize into *tengma and kharang* is very popular but generally the processing technology, the quality of the processed products and packaging can be further improved. There is a need to test better small scale processing machines.

- Increasing preferences of rice over maize -Despite the fact that maize is equally nutritious to rice as it contains carbohydrates, protein, fiber, fat, vitamin B and minerals (calcium, phosphorous and iron), majority of the Bhutanese prefer to eat rice. To make maize more attractive product development and value addition will need careful attention.

4.2.5 Research Publications

The maize research program made the following publication in the 9 FYP.

1. Package of practices for maize. In RNR Technical Recommendations, 2003
2. Highland Maize production practices in east, east central and west central regions of Bhutan: A survey report, 2005
3. Maize variety, evaluation in Bhutan, 2005
4. Manual for maintenance and seed production of open pollinated varieties, 2005
5. Leaf let on chemical weed control in maize, 2005
6. Adoption and Impact of Improved Maize Technologies in Bhutan, 2006
7. Maize Commodity Chain Analysis; Working Document, 2006
8. Five Extension posters on maize diseases, 2007
9. Training materials on maize, 2007.

4.3 Wheat

4.3.1 Area and production

Among the cereal crops grown wheat ranks third after rice and maize. About 18% households grow this crop and it contributes about 2% to the total cereal production (DoA, 2004). Wheat is generally grown in dry land (53.9%) and also in wet lands after rice. Current area under wheat is 7585 acres (Table 10) with a total production of 4192 MT. The national average yield is 553 kg/ac.

Table 10: Area and production of wheat

Dzongkhags	Area acres	Production (tons)	Avg Yield (kg/acre)	AEZ
Bumthang	564	514	911	Alpine/CT
Punakha	591	226	382	Alpine/CT/DST
Trongsa	552	239	433	Alpine/CT/DST/WT
Trashigang	44	24	545	Alpine/CT/DST/WT/HST
Haa	597	337	564	Alpine/CT/WT
Gasa	111	54	486	Alpine/CT/WT
Thimphu	496	529	1067	Alpine/CT/WT
Wangdue	1513	736	486	CT/DST
Paro	988	557	564	CT/WT
Mongar	20	7	350	DST
Lhuntse	91	80	879	DST
S/Jongkhar	108	31	287	DST
Tashi Yangtse	14	8	571	DST
Pemagateshel	6	5	833	HST
Chukka	639	323	505	HST
Tsirang	87	20	230	HST
Zhemgang	272	95	349	HST
Dagana	207	118	570	HST
Sarpang	58	31	534	HST
Samtse	627	258	411	HST/WST
Total	**7585**	**4192**	**553**	

(Source: DoA, 2004)

Looking at the cultivation trend, there is 53 percent reduction in area under wheat crop; however there was increase in average yield by 32.1% between 2000 and 2004. The increase in production was observed only in HST zone. On the other hand reduction in cropping area in Cool Temperate, Warm Temperate and Dry Sub Tropical zones must have contributed to overall reduction in national area under this crop.

Recommended varieties

Wheat research started in 1982 when CARD was started at Bajo. Out of 2724 entries evaluated, three varieties were released for altitude up to 1800m (spring season) till date. They are Sonalika, Bajoka-1 and Bajoka-2. There was increase in yield trend in HST zone due to the released varieties though there was reduction in cropping area. At present, not much research on wheat is ongoing, mainly due to lack of new genetic materials for evaluation and manpower shortage.

Wheat is an important crop next to rice and maize as staple food grains. It can be grown in areas where rice cannot be grown. Potential areas as determine by the percent contribution of wheat to total cereal production and the number of households growing wheat are Haa, Bumthang, Thimphu, Gasa, Wangdue, Paro, Chukha, Trongsa and Punakha.

Some of the research activities undertaken on wheat by RCs were:

- The research centres maintained the seeds of the earlier released improved wheat varieties
- A few new varieties from India, Bangladesh and Nepal were introduced and evaluated under our conditions.
- Collaborative research on wheat rust disease was conducted with the regional CIMMYT office based in Nepal.

4.3.3 Trade

On an average Bhutan imports 9804 MT (Trade Statistics, 2004) of wheat grain annually. Wheat flour import is also very high and it is mainly used for making bread and other food items. The average annual import value of wheat flour is worth about Nu. 131,183,901.

4.3.4 Challenges and Future Research

Limited technologies/varieties
Wheat has so far received very little research attention and focus, therefore there is a general lack of improved technologies including suitable varieties. The three recommended varieties are of spring type and adapted below 1800 m, hence there are no recommended varieties for winter type and for high altitude areas.

High production cost of domestic wheat
Due to high labour costs, it is always cheaper to import from India than to produce wheat domestically. Hence there is no incentive for farmers to expand their area. It must also be recognized that the food grain crops in general have to compete with other crops as far as income generation is concerned at the farm level and all the evidence is that wheat offers the least returns to investment and the lowest gross margins of all crops.

4.4 Other Cereals

All cereals and other crops including amaranth, perilla etc. other than rice, maize and wheat were included under minor cereals research in view of their acreage under cultivation and utilization perspectives. Due to the lack of clear understanding of crops under minor cereals and also due to too many crops under minor cereals, it was difficult to streamline research activities. Therefore, to enhance in carrying out a focused research, minor cereals are redefined as other cereals, which include millets (finger millet, foxtail millet & common millet), barley and buckwheat.

Other cereals are generally grown as rainfed crops in marginal and sub-marginal conditions of soil fertility and moisture where other productive crops do not perform well. Although other cereals are cultivated from subtropical–temperate climates in various parts of the country, acreage under cultivation and their production are minimal compared to rice and maize. The total acreage under other cereal cultivation is 20.58% (41,498 acres) of the total area under cereals producing only 9.63% (18416 tons) of the total cereal production in the country (DoA, 2005). However, other cereals play important role in diversifying the farming systems, food security and sustainable farming in the marginal areas. Through time with the transition of agriculture to more productive systems, cultivation of millets appears to decline in acreage and utilization. Systematic research on other cereal production needs to be conducted to generate cost-effective technologies and make other cereal farming sustainable.

On other cereals, lack of improved varieties, lack of information on yield loss to pests and diseases, lack of information on crop diversity and lack of understanding on other cereals production were identified as the researchable issues. Therefore, research activities in the 9FYP were conducted to generate basic information on other cereals cultivation, constraints, issues and their role for food security and also introduce or develop superior varieties.

4.4.1 Review of research accomplishments

Information generation

Detailed information on the farming practices of other cereals (Buckwheat, barley, finger millet, foxtail millet & common millet) have been generated through household survey. Household survey on the farming practices of other cereals was conducted in Bumthang, Chukha, Dagana, Mongar, Paro, Pemagatshel, Tashigang, Tashiyangtse, Tsirang, Trongsa, Samtse, Sarpang and Zhemgang Dzongkhags covering different agro-ecosystems. The study was conducted using stratified judgmental method and covered 461 households in the above 12 Dzongkhags. Basic information on the farming practices, crop diversity, utilization, constraints, importance in food security, cropping trend, net returns for other cereals cultivation documented and recommendations on improving other cereals research made. Studies on indigenous millet nursery raising method and alternative method were conducted and information documented. Suggestions for interventions for the same were also made. Detailed information on other cereals are available in separate publications.

Variety improvement

Barley

In view of the proposal on beer factory establishment in Bhutan by one of the New Zealand Companies, studies on the raw materials for beer production were conducted. The local barley varieties were found not suitable for beer production due to the lack of hull, which is required for beer production. Therefore, 47 exotic spring malting barley varieties (Table 11) were introduced from New Zealand and Australia and evaluated under Bhutanese climatic conditions in Bumthang and Trongsa Dzongkhags. Agronomic practices of malting barley production were studied and the basic technology on malting barley production generated. Three malting barley varieties; Otis, Marina and Dan Yanka were identified as potential varieties and the breeder's seeds of these varieties are maintained at RC-Jakar.

To provide more barley variety options for grain purposes to the farmers, over 100 varieties of winter cold tolerant barley varieties from the International Centre for Agricultural Research in the Dry Areas (ICARDA) are being evaluated for their performance under Bhutanese conditions.

Table 11: Number of other cereals germplasms evaluated

Crop	No. evaluated
Buckwheat	29
Malting Barley	47
Finger millet	109
Triticale	22

Finger millet

Finger millet is the most commonly cultivated millet of the three millets (finger millet, foxtail millet & common millet) cultivated in the country. In view of the low yield potential of the local millets, 109 exotic varieties were evaluated for grain yield and other agronomic traits. Two superior varieties (Limithang Kongpu 1 & 2) that are moderately tolerant to blast were released for cultivation by the farmers.

Triticale

As an alternative crop of wheat, 22 exotic varieties of Triticale were evaluated as spring crop for higher elevations such as in Bumthang. The crop performed satisfactorily in terms of yield under Bumthang condition. However, take up by farmers were poor due to the difficulty in threshing and poor grain quality. Therefore, trial and promotion of Triticale was terminated.

Buckwheat
A Japanese sweet buckwheat variety against 18 local varieties was evaluated for grain yield and other agronomic traits. In the first year, the Japanese variety yielded higher than the local varieties. However, in the subsequent years the performance declined. This Japanese variety is still under evaluation. A total of 29 buckwheat varieties have been evaluated.

Conservation
Inventory of other cereals diversity is being prepared in collaboration with the National Biodiversity Centre (NBC), Serbithang as part of the inventory of crop genetic resources. Germplasm of other cereals were collected from different Dzongkhags and submitted to NBC for conservation in the gene bank. Collection and characterization of indigenous cultivars of other cereals have been initiated in collaboration with NBC.

4.4.2 Future Research Outlook

- To make other cereals cultivation more productive and sustainable, there is a need to up-scale research activities through strengthening of research capacity by establishing linkage with relevant international and national research institutions.
- Need to invest more on capacity building, accessing scientific information and germplasm, policy support encouraging basic research besides impact oriented research.
- Collect local cultivar of other cereals, characterize, evaluate through proper trial designs, document and conserve in ex-situ for utilization.
- Improve yield potential of other cereals through research on agronomic practices, selective and introduction breeding.
- In view of the lack of understanding and awareness, there is a need to publish a book on other cereals.

Publications

Dukpa, W. (2006). Minor Cereals and Food Security in the Marginal Areas of Bhutan. *RNR Journal*, Vol.2. pp 73-92

Dukpa, W & Lhamu, G. (2007). *Millets – Disappearing From the Bhutanese Menu.* RC-Jakar, Bumthang.

Dukpa, W. (2006). Buckwheat. *Jakar Maylong*, Issue 13.

Katwal, T.B, Penjor, T, Wangdi, S, Adhikari, N.B, Domang & Chhetri, P.B. (2007). Indigenous Millet Nursery Raising in *Tseri*: Conservation Concerns and Research Options. *RNR Journal*, Vol. 3. pp 119-127.

4.5 Oilseeds

The major oilcrop grown in Bhutan is rapeseed-mustard or *Brassica campestris* var. toria (synonym tori or peka) which is predominantly grown and mostly referred to as mustard in Bhutan. Besides, farmers also grow locally available traditional variety of *Brassica campestris* var. yellow sarson. Yellow sarson is preferred due to more oil content and from religious point of view. The duration of yellow sarson is comparatively more and has almost same yield level as of toria. In general, mustard refers to *Brassica* oilcrops and the same terminology shall be followed in this report. In Eastern districts of Bhutan (Yangtse, Trashigang, S/jongkhar, Mongar, Pemagatshel and Lhuntse) soybean is also grown mainly as a mixed crop with maize but is not used for oil extraction purpose.

The other oil crops grown in patches are groundnut, sunflower and Niger seed. Groundnut cultivation is restricted to few farmers and kernels are consumed as such by households and oil is usually not extracted. The confectionary type sunflowers are restricted to kitchen garden at isolated places. Niger seed cultivation is limited to mid hills, particularly on marginal and poor lands having low fertility and the acreage is negligible. There are also some native oil bearing species (Yika, Pangtse, Shingtse), which are used for oil extraction. The oilseed crops in Bhutan are grown to sustain the needs of households and do not attach any commercial value at present. The strategy for marketing and processing of oil is lacking.

4.5.1 Area and Production

The mustard production was only 1900 MT in 1981 which increased to 3476 MT in 1984 and 3900 MT in 1986. The production declined to 1695 MT in the year 2000 and 1548 MT in 2004. However, the national productivity during 2004 was highest (372 kg/acre), but the area has declined (Table 12).

Table 12: Area, production and productivity of mustard in Bhutan

Year	Area (acres)	Production (MT)	Productivity (Kg/acre)
1984	12318	3476	284
1999 (sample survey)	7993	1401	186
2000 (Census, 2001)	8525	1695	199
2004 (DoA ,2004)	4383	1548	372

It is apparent that the acreage is gradually diminishing. It was observed that in prominent mustard growing districts like Tsirang, S/jongkhar, Dagana, Sarpang and Trashigang, the acreage under mustard has gone down in last two decades compared with 1984. The import of cheaper oil from India has become a disincentive for domestic production.

The harvested area, production and yield of mustard in few important Dzongkhags are given in Table 13.

Table 13: Area, Production and Yield of mustard in some important Dzongkhags

Dzongkhag	Area (acre)	Production (‘000 kg)	Yield (Kg/acre)
Samdrupjongkhar	1050	211.5	201
Sarpang	1229	188.5	153
Chhukha	771	163.9	213
Dagana	690	154.8	224
Trasigang	588	146.4	249
Punakha	937	146.0	156
Thimphu	214	133.3	623
Wangdue	590	106.7	181
Tsirang	630	99.0	157
Samtse	563	85.3	152
Paro	165	48.6	294

The average yield varies from 153 to 623 kg/acre. Thus, there is wide variation in yield and some Dzongkhag (Sarpang, Punakha, Tsirang, Samtse and Wangdue) have less than national average yield (199 kg/acre). Adopting improved technology can enhance the yield. Farmers do not adopt any plant protection measures in mustard crop but are aware of the problems of White Rust, Saw-fly and Aphids. Many farmers do not wish to control aphids due to religious reasons. The use of fertilizers in mustard is also very low. The productivity of mustard in Thimphu is highest (623 kg/acre) in comparison with any other Dzongkhag (RNR Statistics 2000). This may be primarily due to cultivation of mustard in potato based system with very high chemical fertilizers used in potato. The major mustard producing Dzongkhags are: S/jongkhar, Sarpang, Chhukha, Dagana, Trashigang, Punakha, Thimphu, Wangdue and Tsirang, S/jongkhar and sarpang. S/jongkhar and Sarpang account for one-fourth of the total acreage.

A general increase in yield over the years (1989-2005) is recorded with few fluctuations in some years (Fig 2). The high yield (peaks) in some years is a combined affect of better quality seed, good weather conditions and high soil fertility and the reverse is true for those years with low yield (lows). As different data collection methods (survey, random sampling) were used to gather data on production and acreage over the years, part of the fluctuations (peaks and lows) can be explained by different data collection methods used.

The mustard yields were below 400 kg per hectare in 1989 and over the years has increased to 1000 kg per hectare. These yields are abject low figures and there is a need to educate the farmers in improved cultivation practice combined with access to quality seed. The existing low yields are due to poor crop management practice combined with low soil fertility.

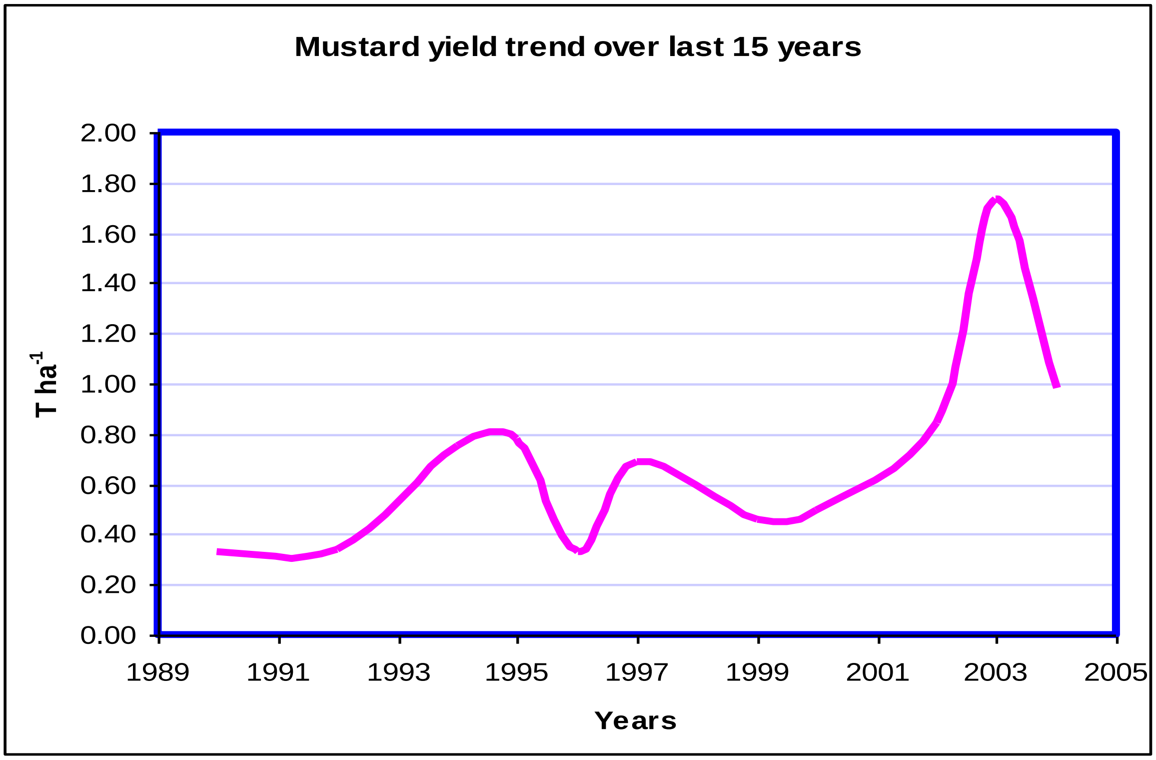


Fig 2: Mustard yield trend from 1989 to 2004

A random sample survey was conducted in 2000 in the mustard growing areas in which 1619 farmers were interviewed. According to the survey, 87.7% of the mustard growers cultivate local varieties, whose yields are as low as 95.9 kg per acre with a high standard deviation indicating wide yield variation between the farmers. Comparatively, only 5.6% of the mustard growers cultivate improved varieties, the yields of which are higher by more than 200% (229.8 kg per acre). Similarly, high standard deviation of improved varieties indicates wide variation of yields among farmers. Interestingly, only 6.7 % of the mustard growers cultivate both local and improved varieties and the farmers cultivating both varieties harvest a yield of 177.1 kg per acre.

4.5.2 Mustard production practices

Cultivation methods
Farmers use traditional practices and methods of mustard cultivation which result in sub-optimal management regimes and low production. This is in fact typical of any subsistence farming – the challenge now is to go past such a stage to become more commercialized and specialized, exploiting the environmental and agro-ecological potentials of a given agro-economic zone.

Labor Shortage
According to mustard CCA survey, use of labour input is high (70 person days per ha) in mustard cultivation, and farm labour in Bhutan is scarce and costly (Nu 100 per day with 2-3 meals provided). Scarcity stems from a small population

and competing opportunities such as working off-farm, children enrolling in schools and monastic institutions, migration to urban centres etc. In such a scenario, reducing the labour requirement possibly through improved practices and increased use of farm machineries, is called for.

Farming Equipment

Farming tools and implements are still largely traditional with very low use efficiency. For instance, the local plough, wooden plough shear and sickles which lack serration are inefficient; simple modifications to such implements can lead to greater efficacy and span. AMC can lead in this area. Farm mechanization, to the extent possible, needs to be accelerated. Options for machinery ownership by groups can be explored to ensure availability, instead of individual ownership.

Crop loss due to wild animals

Crop loss to wild animals such as elephants, wild boar, deer and monkeys is substantial and any prevention of such losses adds to the total production. It is often times beyond the means of a farmer to offset crop losses, except for crop guarding which results in loss of productive time of the farmer. Wild animals are a menace to farmers at the national level and much is talked about even in the National Assembly and outside it, but nothing concrete has been done so far.

Poor soil fertility

This issue has been ranked as a major constraint to mustard production. Most of the respondents expressed that a mustard crop following maize yields very low as maize is a voracious feeder of nutrients. The subsistence nature and level of mustard production discourages farmers from using chemical fertilizers as it involves cost without any cash return as most of production is used for household consumption.

Pest and disease incidence

Rapeseed-Mustard crops are damaged by an array of insect-pests and diseases of which mustard aphid; Alternaria leaf spot and white rust are the major ones. Average yield loss of 35 to 50% has been observed due to insect pest and diseases in these crops.

Mustard has been a neglected crop in Bhutan in terms of research and development. So far, RNR-RCs have released 4 varieties of mustard till date. They are Type-9, M-27, Bajo Peka 1 and Bajo Peka 2. Of them, Type 9 and M-27 are the most commonly grown mustard varieties in low to high altitude zone.

4.5.3 Mustard processing and marketing

Most of the mustard growers (78%) use mechanized method of oil expelling (Mustard CCA, 2006) whereas only 12% of farmers use manual method of oil expelling. Farmers using mechanized method admit that distance to oil expellers, high charge for expelling and low quality of expelled oil are the major problems faced. On the other hand, farmers expressed that the time taken for expelling is less and there is higher oil recovery with mechanized oil expellers. The farmers using manual method get better quality of oil, better price and there is no charge for expelling oil. On the other hand, the manual method is time consuming, labour intensive and less oil recovery is achieved. The oil cake quality is better with manual method than mechanized due to more oil retention in the oil cake.

According to the Mustard CCA, 2006, each expelling unit processes only 5590 kg of mustard per year equivalent to operation for 14 days in a year (112 hours). This is gross underutilization of the oil expelling unit and hence the venture is not profitable at all. Hence, both expelling units and paddy mills are set up together under one roof by the operators in order to increase the profitability of the operators. The oil expelling units are either run by diesel or electricity and the operating costs are high due to low margin accrued from minimum volume of mustard processed.

Mustard production in Bhutan is for home consumption. According to the mustard CCA survey in 2006, only 20% is reported as sold to the market. There is no sizeable marketable volume from a single household or producer as land holdings are small. There is a need to pool together the small surpluses from individual households and bring to the market. We need entrepreneurs, middlemen, brokers and traders to get involved. This may not be a lucrative business to start with, and government has to provide some form of incentives or subsidies.

The proposal of setting up large scale oil expelling units fits well with the idea of getting the small surpluses out of the villages and production pockets. In the course of time, farmers will be induced to produce more for the market if reasonable price and door/farm gate collection could be assured. A possible marketing option is the link between FCB and oil expellers so that oil expellers provide mustard oil to FCB for selling.

The above initiatives could grow bigger and lead to formation of farmers' associations and co-operatives for mustard production and marketing, which is in fact a cherished goal of the Ministry of Agriculture. The government, however, must invest in development of infrastructures, farm roads, transportation facilities etc.

4.5.4 Key issues in mustard production

The following key issues emerge, which need a closer look at the operations at all levels in the chain. The oilseed crops have not received the desired attention in the past due to which the acreage has declined. The major constraints in oilseeds production are as under:

- Inefficient method of oil extraction/long distance to mechanized oil expeller units

- Cultivation on small and marginal lands with deteriorating soil fertility
- Adoption of low yielding traditional varieties due to lack of suitable improved varieties for different agro-ecological situations.
- Inadequate availability of quality seeds of improved varieties
- Sub-optimal agronomic practices and non-adoption of improved agro-technology.
- Incidence of diseases (white rust, downy mildew and Alternaria blight) and pests (Sawfly and aphids)
- Limited availability of germplasm material and narrow genetic base of cultivated mustard varieties in Bhutan
- Lack of crop promotional programs on mustard in remote areas.
- Inadequate knowledge and skills of agriculture extension agents on the improved oilseeds production technology.
- Absence of collaboration with leading international organizations involved in oilseeds research.
- Lack of desired policy framework for oilseeds sector

4.6 Grain Legumes

Although the Field Crops Research Program includes grain legumes as a component, there is hardly any research being undertaken in the research centres or in the farmers' fields. This is due to severe shortage of manpower to initiate and lead research on grain legumes. The following information has been condensed from a national legumes survey conducted by the National Soils Services Centre in 1999.

4.6.1 Diversity of Legumes

Grain legumes are an important component of the Bhutanese farming systems. They are grown in diverse land use systems such as dryland, wetland, kitchen gardens and *tseri* in different cropping systems and seasons depending on the altitudes and the species. However, over 75% of the national legumes area is on drylands (National Legumes Survey, 1999). The survey of 1999 recorded a total of 16 species grown in the country, including a few unidentified species (Table 14). The most widely grown species across the country are *Glycine max, Phaseolus vulgaris, Pisum sativum* and *Vigna* spp.

Table 14: Legume species cultivated in the country by altitudes

Legume species	**Altitude in m**					**Total no of villages**
	200-600	**600-1200**	**1200-1800**	**1800-2400**	**Above 2400**	
Arachis hypogea	-	-	9*	2	-	11
Cajanus cajan	18	-	-	-	-	18
Dolichus lablab	-	-	3	-	-	3
Glycine max	18	46	183	108	3	358
M. uniflorum	6	-	-	-	-	6
Phaseolus lunatus	21	1	-	-	-	22
Pisum sativum	10	2	28	16	5	61
Psophocarpus tetragonolobus	2	-	-	-	-	2
Phaseolus vulgaris	32	48	170	98	2	350
Phaseolus coccineus	-	-	6	1	1	8
Phaseolus spp	3	-	11	2	4	20
Vigna mungo	30	12	8	3	-	53
Vigna radiate	19	-	12	1	1	33
Vigna umbellate	3	19	69	22	-	113
Vigna unguiculata	-	12	25	3	-	40
Vigna spp	4	2	14	7	-	26
Unidentified spp	3	1	1	-	-	5
Total no. of species	13	9	13	11	6	

* the figures indicate the number of villages in which each species was recorded
Data source: National Legumes Survey, 1999

The grain legumes are known by various names in different languages and dialects in the country (Table 15). The use of the local name, however, is often unclear whether it applies to a specific variety or is simply a general name applicable to all varieties of that species. Most farmers grow traditional varieties and maintain their own seeds. Reasons for growing legumes by the farmers include: food source, income source, availability of land and seeds, fodder for livestock, easy management, improvement in soil fertility, used for religious ceremonies and less damage by wild animals (NLS, 1999).

Table 15: Legume species and their local names

Latin name	**Dzongkha**	**Sharchopkha**	**Lhotshamkha**
Arachis hypogea	Batha semchum	Badam	Badam
Cajanus cajan	Tyeu	Rahari	Rahari dal
Dolichus lablab	Semchu karp	-	-
Glycine max	Semkarp	Libi	Bhatmas
Pisum sativum	Beysem, Thachem semchu	Bray changmo Brashangmo	Matar
Phaseolus vulgaris	Pata semchum Moram, Bogola	Broktang oray Nakmay	Bori, kanchi bori, ghew bori
Phaseolus spp	Batha semchum Guma semchum	Semchum	Hiudey bori, singvi
Vigna mungo	Semchu	Shakpu	Kalo dal
Vigna radiate	Huchum	Mosum, Shakpu dal	Moong dal
Vigna umbellate	Semchu kaap	Gakpu, Shengje	Bori
Vigna unguiculata	Semchu	Senji, Guibee	-

Data source: National Legumes Survey, 1999

4.6.2 Area and Production

Data on the area and production of grain legumes are often incomplete and fragmented. The National Legumes Survey of 1999 estimated 32,990 ha (Table 16) of land under legumes cultivation, which is about 11% of the national arable area. Some other sources cite lower figures. By region, the eastern and west-central regions have the greatest percent of land under legumes. The most important legume species in terms of cultivated area are *Glycine max*, different *Phaseolus* spp and *Pisum sativum*. The average yields of grain legumes are around 497 kg/ha (NLS, 1999) under monocropped conditions and slightly lower when intercropped (457 kg/ha). The total annual production of legumes would be around 14,000 tonnes.

Table 16: Estimates of area grown to legume species by altitudes

Legume species	Altitude in m					Total (ha)
	200-600	600-1200	1200-1800	1800-2400	Above 2400	
Arachis hypogea	-	-	91.6	14.3	-	106
Cajanus cajan	32	20.6	-	-	-	52.6
Dolichus lablab	-	-	86.6	-	167.6	254.2
Glycine max	124	1490	5280	2944.5	34	9874
Pisum sativum	-	192	1172.5	225.5	2055	3969
Phaseolus vulgaris	269.2	721.9	2909	361.5	186.2	4448
Phaseolus coccineus	-	-	56.3	9.3	16.2	81.8
Phaseolus spp	278.1	541.3	2571.2	1576	351.8	5319
Vigna mungo	72.9	64	234.8	-	-	372
Vigna radiate	40	-	590.3	647	3.2	1286
Vigna umbellate	-	355.5	1504.5	1625.1	-	3485
Vigna unguiculata	61.5	262.3	889.9	352.2	-	1566
Vigna spp	120.2	971.2	847	-	12.2	1950
Unidentified spp	48.6	164	14.6	-	-	227
Total no. of species	1047	4783	16249	7756	3155	32990

Data source: National Legumes Survey, 1999

4.6.3 Available improved varieties

RNRRCs have so far evaluated, identified and released 3 improved varieties of soybean and 2 varieties of mungbean (Table 17: *Improved varieties of soybean and mungbean*.

Table 17: Improved varieties of soybean and mungbean

Crop	Variety	Release year	Releasing agency	Altitude (m)	Cropping system
Soybean					
One Daughter	One Daughter	1994	DSC	<2000	Maize based
Bragg	Bragg	1994	DSC	<2000	Maize based
GC 86018-427-3	Khangma Libi-2	2002	RC Wengkhar		Maize based, intercrop
Mungbean					
KPS-2	KPS-2	2002	RC Wengkhar	<2000	Rice and maize based
Bari Mung -2	Bari Mung 2	2002	RC Wengkhar	<2000	Rice and maize based

5. Human Resource Development

During the 9FYP, human resource development formed an important component of the field crops research program. It consisted of researchers pursuing their higher degrees at MSc level, research assistants attending short training courses and also researchers and administrators participating in regional and international meetings, seminars, workshops and conferences related to field crops program. The following staff completed their MSc program:

- Ms Mumta Chettri, Research Officer (Field Crops) of RNRRC Yusipang completed her MSc in Crop Breeding and Improvement from the University of Wageningen, Netherlands in 2004.

- Mr. Wangda Dukpa, Research Officer for Field Crops in RC Jakar pursued his MSc in Tropical Agricultural Development (TAD) in the University of Reading, U.K. in 2005.

- Mr. Sangay Wangdi, Research Officer, RC Bajo, also pursued his MSc in Tropical Agricultural Development (TAD) in the University of Reading, U.K. in 2005.

- Mr. Kencho Wangdi, Research Officer, RC Bajo completed his MSc in Agricultural Economics in the University of Sydney in Australia in 2006.

Apart from degree training, several research staff attended short training courses in crops such as rice and maize. Researchers also attended relevant workshops and meetings as outlined in Table 18.

Table 18: Human resource development details during the 9FYP

Year	Training Program/Workshops/Meeting	Participants
2002-2003	Training on Rice Breeding Program at IRRI	Karma
	Rice Production Training at IRRI	Kalpana Rai
2003-2004	International Rice Conference at Malaysia	Mahesh Ghimiray
	Training on DSSAT and GIS tools in Thailand	Mahesh Ghimiray & TB Katwal
	CBNRM Workshop at Philippines	Mahesh Ghimiray
	On the Job Training on Maize in Nepal	TB Katwal
2004-2005	Training on Participatory Research and Development in Thailand	Zangmo
	Training on Rice cultivation in Japan	TB Katwal
	BUCAP workshop in Thailand	Mahesh Ghimiray

Year	Training Program/Workshops/Meeting	Participants
2005-2006	International Rice Genetics Symposium in Philippines	Mahesh Ghimiray & Mumta Chhetri
	Plant Breeders meeting in Philippines	Neelam Pradhan and PL Giri
	Plant Genetic Resources and Sustainable Agriculture training at Thimphu	Kalpana Rai and Lhab Gyem
2006-2007	Meeting on Rapeseed Mustard Project Development in India	Mahesh Ghimiray
	Attend Annual Maize Review & Planning meeting in Nepal	Sangay Tshewang
	Training on Rice cultivation in Japan	Sangay Wangdi
	Training on Upland Rice Production in Thailand	Namgay Wangdi
	Study Visit on Commodity Chain Analysis in Thailand	Mahesh Ghimiray
	Meeting on Temperate Rice Research Consortium at Korea	Mahesh Ghimiray
2007-2008	Training on Rice Breeding Course at IRRI	Sangay Tshewang
	Attend Symposium on System of Rice Intensification in India	Cheku Dorji
	Study visit to Nepal	Wangda Dukpa, Gyem Lham, Deki Pem, Neelam Pradhan.
	International workshop on Development Oriented Research Methods in Thailand	Mahesh Ghimiray
	International Plant Breeding Conference in Vietnam	Sangay Tshewang
	Meeting on Access and benefit sharing from Briodiversity Resources in India	Mahesh Ghimiray

6. Summary and Conclusions

Field crops research program includes cereals (major cereals like rice, maize, wheat, and other cereals like barley, buckwheat and millets), oilseeds (rapeseed-mustard) and grain legumes (soybean, groundnut, mungbean). Rice is the staple food of the majority of the Bhutanese population. The per capita milled rice consumption ranges from 167 kg to 262 kg per annum. Domestic rice production does not meet the national requirement. The overall self-sufficiency level in domestic rice production is only about 50%. The average rice import from 1995 to 2000 was about 33,000 t per year. Recently, the annual import amounts to more than 40,000 t.

Rice is grown from tropical lowlands (200 m) in the south up to elevations as high as 2800 m in the north. Because of Bhutan's rugged topography, rice fields are generally terraced. Rice environments are broadly grouped into three altitude zones which also reflect different temperature regimes. The total area grown to rice was 25,295 ha in 2005, with a total rice production of 67,607 t. The average yield is around 2.5 t/ha. An impact study in 2004 showed the national rice output increased by 5,000 to 10,000 t per year, the farm-gate values of which are Nu 60 million to Nu 121 million per year, respectively. Adoption of Improved technologies increased the farmers' net income of more than Nu 9,000/ha. This means a gain in net returns nationally of Nu 58 million to Nu 118 million. Around 60% of the households are cultivating released varieties in some 35% of the rice area. Around 68% of the households have achieved self-sufficiency in rice. Adopters of improved technologies have more than 110% more cash income than non-adopters. This could be partly due to improved rice yields that enabled farmers to diversify into high value cash crops. The rice research program has been a major contributor in building the research capacity of the country.

Maize is a major food crop of the country and is cultivated by 69% of the rural households for subsistence. It is cultivated across the country and it ranks first in terms of the area and production of food crops. Maize plays a critical role in the household food security as it is a staple food. It is estimated that 80% of the total production is consumed at the household level by the farmers; this is valued at Nu. 353 million annually. About 6% of the total production is sold which serves as an important source of household income. The processed maize products are also important source of household income.

The national maize impact assessment survey estimated the yield of improved varieties to be 2.47 t/ha as against 1.17 t/ha of the traditional varieties with a yield difference of 110%. The estimated gain in production for 2004 that could be directly attributed to the maize program is in the range of 12,000 to 14,000 tons. The value of this increased production is Nu 121 to 138 millions at the price of Nu 10,000 per ton. Approximately 8% of the total production is estimated to be surplus production (over 7000 tons). The adoption of improved maize varieties (IMVs) underpinned this increase in production. These IMVs are adopted by 60%

of the surveyed households and planted to 49% of the total maize area. Yangtsipa, the first IMV released, is the most popular variety. It is planted to over 90% of the area cultivated to IMVs in both altitude Zones. The main reasons for adoption of the variety were its high yield potential and resistance to lodging. Improved crop management practices such as seed selection, intercropping with maize, double weeding and application of inorganic fertilizers are increasingly adopted for IMV and traditional maize varieties (TMV) cultivations. Overall, the yield advantage of IMVs over TMVs is 110%. The percentage gain in yield translated into absolute increases of 1300 kg per ha.

Severe incidences of Gray Leaf Spot was observed at elevations above 1800m asl. At the elevations 1700-1800m asl both Gray Leaf Spot and Turcicum Leaf Blight were prevalent. Below 1700 m asl, Turcicum Leaf blight was more prevalent, but with incidences of lesser economic significance. To combat the disease a long term breeding program to select yellow endosperm maize tolerant to the disease has been started with support of CIMMYT. Cercospora-tolerant maize germplasm available from CIMMYT have been introduced and selection started. For the short term a new systematic fungicide has also been recommended. Training and awareness campaign on the disease has been started in collaboration with the Department of Agriculture. Training materials and five different posters on the disease have been developed for trainings of farmers and the Extension Agents. Training of Extension Agents on maize production and disease management in the different Dzongkhags has also been started.

Among the cereal crops grown wheat ranks third after rice and maize. About 18% households grow this crop and it contributes about 2% to the total cereal production. Wheat is generally grown in dry land (53.9%) and also in wet lands after rice. Current area under wheat is 7585 acres with a total production of 4192 MT. The national average yield is 553 kg/ac. Wheat research started in 1982 when CARD was started at Bajo. Out of 2724 entries evaluated, three varieties were released for altitude up to 1800m (spring season) till date. They are Sonalika, Bajoka-1 and Bajoka-2. There was increase in yield trend in HST zone due to the released varieties though there was reduction in cropping area. At present, not much research on wheat is ongoing, mainly due to lack of new genetic materials for evaluation and manpower shortage.

The major oilcrops grown in Bhutan is rapeseed-mustard or *Brassica campestris* which is predominantly grown and mostly referred to as mustard in Bhutan. Besides, farmers also grow locally available traditional variety of *Brassica campestris* var. yellow sarson. Yellow sarson is preferred due to more oil content and from religious point of view. In Eastern districts of Bhutan soybean is also grown mainly as a mixed crop with maize but is not used for oil extraction purpose. The other oil crops grown in patches are groundnut, sunflower and Niger seed. Groundnut cultivation is restricted to few farmers and kernels are consumed as such by households and oil is usually not extracted. The confectionary type sunflowers are restricted to kitchen garden at isolated places.

Niger seed cultivation is limited to mid hills, particularly on marginal and poor lands having low fertility and the acreage is negligible. There are also some native oil bearing species like Yika, Pangtse and Shingtse, which are used for oil extraction. The major constraints in oilseeds production are inefficient method of oil extraction/long distance to mechanized oil expeller units, cultivation on small and marginal lands with deteriorating soil fertility, inadequate availability of quality seeds of improved varieties, sub-optimal agronomic practices and non-adoption of improved agro-technology, incidence of diseases (white rust, downy mildew and Alternaria blight) and pests (Sawfly and aphids) etc.

Grain legumes are an important component of the Bhutanese farming systems and are grown in diverse land use systems such as dryland, wetland, kitchen gardens and *tseri* in different cropping systems and seasons. However, over 75% of the national legumes area is on drylands. A national survey in 1999 recorded a total of 16 species grown in the country, including a few unidentified species. The most widely grown species across the country are *Glycine max, Phaseolus vulgaris, Pisum sativum* and *Vigna* spp. Data on the area and production of grain legumes are often incomplete and fragmented. It is estimated that 32,990 ha of land is under legumes cultivation, which is about 11% of the national arable area. The average yields of grain legumes are around 497 kg/ha under monocropped conditions and slightly lower when intercropped (457 kg/ha). The total annual production of legumes would be around 14,000 tonnes. Although the Field Crops Research Program includes grain legumes as a component, there is hardly any research being undertaken in the research centres or in the farmers' fields. This is due to severe shortage of manpower to initiate and lead research on grain legumes.

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