ABOUT THIS REPORT

This is the fourteenth technical report produced from this Centre since 1984. The report is a comprehensive summary of research and development activities undertaken by the Center, both at the research station and in farmers' fields. This report covers the period from July 1998 to June 1999 to coincide with the RGOB's financial year. A reference to winter crops such as wheat, oilcrops and some vegetables therefore means that they were sown in November 1998 and harvested in April-May 1999. The summer crops are mostly planted in May-July and harvested in October-November (1998). Some experiments are reported completely while others are ongoing and only interim results are reported.

This report follows the style of the preceding reports, wherein program-wise presentation is done. Major research programs are the Field Crops, Horticulture (fruits and vegetables), Livestock, Forestry and Systems Resource Management including on-farm research, integrated pest management and water management research. The report presentation follows the above sequence.

Abbreviations used in this report are listed in the following pages. The report uses the International System of Units (SI) with some exceptions. Control or check normally means an untreated control. Grain yield is calculated as rough rice at 14% moisture content (mc), wheat at 12% mc and oilseeds at 8% mc.

Yield refers to grain yield unless otherwise stated. Fertilizer amounts are given in terms of elements (N, P, K, Zn etc) and not in the older conventional oxide formulations.

Pedigrees are indicated by a slant bar (/) rather than by multiplication sign (x). Unless otherwise stated, the morphological characters of rice and insect pest damages are based on scales in the 'Standard Evaluation System for Rice' published by IRRI, Philippines.

A single asterisk (*) means a significant difference at the 5% level of significance and ns means not significant.

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ABOUT THIS CENTRE

Established in 1982 as the Centre for Agricultural Research and Development (CARD) basically to undertake research on rice and rice-based crops, it was renamed as the Renewable Natural Resources Research Centre (RNRRC) in 1995 to incorporate research on livestock and forest that are inseparable components of the Bhutanese farming systems. The Centre is located at Bajo (1300m) in Wangduephodrang, which is about 70 km west of the capital Thimphu.

RNRRC Bajo is designated as the Coordinating Centre for Field Crops (cereals, oilcrops, and legumes) Research and Water Management Research at the national level. At the regional level, this Centre is mandated to undertake relevant research for its client Dzongkhags of Wangduephodrang, Punakha, Gasa, Tsirang and Dagana in arable agriculture, livestock and forestry. The Centre has a 64 ha research farm. Recently, the facilities of the Centre have been upgraded with the construction of the new administrative cum laboratory building.

The Centre undertakes an intensive program of research and extension through its on-farm research program; training of extension personnel and farmers; and other interdisciplinary activities both at the national and local levels. It introduces, adapts and develops technologies suitable for the local agroecological environments and helps farmers raise their standard of living through increased incomes and sustainable farm production. Research is based on the policy guidelines of problem orientation, disciplinary and inter- disciplinary focus, relevance, environmental and institutional sustainability and equity. Research strategies aim at improving the productivity, profitability, stability and sustainability of farming systems while conserving the fragile environment and fostering development of an integrated crop-livestock-forest system.

RNRRC Bajo receives technical support and improved germplasm from IRRI, AVRDC, CIMMTY, ICRISAT, ICARDA, CIP and a number of other regional agricultural institutes. In addition to the RGOB core budget for recurrent expenditure, the Centre also receives support in the form of field and laboratory equipment, vehicles, technical expertise etc. from IDRC-SDC through the IRRI-Bhutan Rice Farming Systems Project, and other development projects of the region.

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ACRONYMS

AET	Advanced Evaluation Trial
AVRDC	Asian Vegetable Research and Development Center
a.i.	Active ingredient
BL	Blast
CAN	Calcium Ammonium Nitrate
CARD	Centre for Agricultural Research and Development
CIMMYT	International Maize and Wheat Improvement Centre
cm	centimeter
CV	coefficient of variation
DMRT	Duncan's Multiple Range Test
DAT	Days after transplanting
FLW	Flowering
FYM	Farmyard manure
gm	gram
ha	hectare
P.Ht.	Plant Height
ICRISAT	International Crops research Institute for the Semi-Arid Tropics
ICARDA	International Centre for Agricultural Research in the Dry Areas
IDRC	International Development Research Institute
IET	Initial Evaluation Trial
IPM	Integrated Pest Management
IPNS	International Plant Nutrient Study
IRCTN	International Rice Cold Tolerance Nursery
IRRI	International Rice Research Institute
K	Potassium
LSD	least significant difference
m	meter
MAT	maturity
MoA	Ministry of Agriculture
MP	Murate of Potash
N	Nitrogen
NASEPP	National Seed and Plant Program
NPPC	National Plant Protection Center
No.	Number
n.s.	Not significant
P	Phosphorus
PET	Production Evaluation Trial
PRET	Pre-production evaluation trial
RCB	Randomized complete block
RGOB	Royal Government of Bhutan
REID	Research, Extension and Irrigation Division
RNRRC	Renewable Natural Resources Research Centre
SAVERNET	South Asian Vegetable Research Network
s.e.	Standard error
S.E.D.	Standard error of difference
sqm.	Square meter
SSP	Single Super Phosphate
t or mt	metric tones (1000 kg)
WMR	Water Management Research

EXECUTIVE SUMMARY

FIELD CROPS

Field crops research aims to increase and sustain the productivity cereals (rice, maize, wheat, and other minor crops), oilseeds (mustard) and grain legumesin the long run. The short-term objectives are to identify, adapt or develop appropriate and affordable technologies for optimising the production of field crops.

Rice

Research on rice attempts to improve rice production using appropriate varieties and production management techniques. The general aim of variety trials is to identify suitable varieties with high yield potential, medium height, optimum maturity and resistance to prevailing pest and diseases. In AET, 20 entries were tested. Statistical analysis of grain yield showed that IR 64 was the top yielder (5.86 t/ha) although several crossbred lines such IR65239-B-B-47-B, CARD20-21-3-2-3-1-1, IR62467-B-R-B-B-1-1-B produced yields statistically comparable to IR 64. Local check Zakha yielded 3.82 t/ha.

Two sets of IETs were established, composed mainly of breeding lines, to select promising lines/varieties for further evaluation. Analysis of IET-1 showed that several test varieties produced significantly higher grain yields than Zakha. However, none of the entries could perform better than IR 64. Results from IET-2 showed that IR62467-B-R-B-34-2B, a cross between Attey and Suweon 358 produced the maximum yield of 5.97 t/ha. Several other breeding lines also produced significantly higher grain yields than Zakha. The elite selection from this trial will be further evaluated in the following season.

Seven sets of Observation Nurseries, consisting of both indigenous cross-bred and introduced materials were conducted. In general, most test entries produced grain yields higher than the local check Zakha. The observed grain yield ranged from 2.64-9.08 t/ha. Maturity ranged from 131-164 days. Plant height was recorded between 71-133 days. More than 450 entries were screened from the seven nursery sets.

On-farm evaluation aims to identify suitable location-specific varieties under farmers' management levels. In PRET, four improved lines were tested in six locations. Results indicated that H2O2-7-1-1-1, an Argentine line, produced the highest yield of 4.89 t/ha, averaged across locations. IR56346-1-1-2-1-9-1-1, a cross between Wangdu Kaap and BG90-2, did well outyielding the local Tan Tshering by 0.83 t/ha. In PET, 5 elite lines were widely tested. In most locations the test variety performed better than the local varieties. In Punakha, CARD21-10-1-1-3-2-1 yielded highest (7.61 t/ha) averaged across locations. On an average, the improved test lines yielded 1.42 t/ha higher than the local varieties. In Wangdue, the highest yielding line was IR61331-2-25-2-3-2-2 (7.28 t/ha), which is a cross of Paro Maap and IR41996. Farmer-collaborators also maintain seeds of the varieties they like and even distribute or sell to their neighbours, thus adding to the onfarm varietal diversity.

Collection, characterisation and rejuvenation of rice germplasm are considered as important activities in variety development. In 1998 a total of 154 local rice

varieties from different altitudes were rejuvenated and characterised at the station.

Grain Legumes

Although legumes are not presently very popular in the Bhutanese diet, research is being carried out to tap their potential as a source of cash generation and restoration of soil fertility. Variety evaluation was carried out on groundnut, soybeans and mungbeans. ICGV 86699, ICGV 87921 and Kadiri were identified as promising varieties of groundnut. Of the 30 mungbean entries tested in two trials, VC 6173 lines were selected for further evaluation.

Crop Management Research

Research on crop production management included the determination of yield potential of released and pre-release rice varieties, and organic crop production using a combination of organics and Effective Micro-organisms (EM).

With the objective to try and achieve the maximum yield potential of rice using a higher dose of N fertiliser (150:40:20 NPK Kg/ha) and FYM (14t/ha) combined with recommended management practices, 10 rice varieties were subject to an RCBD with 3 replications. Results showed that IR 64 produced the highest grain (9.07 t/ha) and straw (14.8 t/ha) yields amongst all test entries. The high fertility regime inversely affected the performance of Chumro and No.11 varieties. Chummro and IR61331-2-25 were affected by panicle blast, sheath blight and sterility thus lowering their yield.

Preliminary and indicative results from the use of EM in cereals (rice, wheat, mustard and maize) show that moderate yields can be obtained without chemical fertilisers. Improvements in the physical and nutritive qualities of the soil are also becoming evident. However, detailed analytical studies remain to be done. Weed infestation is a major problem, as weeds are not effectively suppressed using EM alone.

HORTICULTURE

Subtropical Fruits

Research on subtropical fruits concentrated on introduction and evaluation of new varieties, both on station and on farm. Through IHDP-II, five cultivars each of avocado, pecan, chestnut and walnut have been imported from California and Australia and planted in the trial orchard for evaluation. From the on-station varietal adaptability trials new results have been generated citrus, mango, apricot, peach and pear. In citrus two satsuma cultivars, three mandarin cultivars, one tangelo, one tangor, one sweet orange, one lime and two lemon cultivars have been identified as potential crops. Two apricot cultivars have shown potential to add to the production of stone fruits in the region. The mango cultivars Himsagar and Dasheri along with the hybrid Amrapalli have huge scope for cultivation in some areas as these cultivars are far superior over those presently cultivated in the country. The sub-tropical apple cultivar Anna is

adaptable to the conditions of the centre and is a potential crop for the farmers in the sub-tropical regions.

On-farm evaluation of the promising cultivars has been strengthened with the establishment of three demonstration orchards at three elevations in two dzongkhags. All promising cultivars will be planted in these orchards as and when there is adequate materials propagated at the centre. A few more demonstration orchards are planned for the remaining dzongkhags in the next season. New techniques of propagation such as veneer grafting of mango, patch-budding of walnut and cleft grafting of avocado has been successfully tried. Mango propagation can now be conveniently carried out with this technique. Walnut propagation is also simplified with the adoption of the patch budding at the right time in the season. Avocado can also be easily propagated with the adoption of small cleft grafting under plastic house in the spring. These techniques are also imparted to the farmers in regular trainings of extension and farmers in nursery propagation techniques.

Equal efforts have also gone in collecting the local wild germplasm to evaluate their use in further development. A good collection of the local wild avocado, popularly known as Guli, has been established in the nursery and these materials are available for trial use as rootstocks for the improved cultivars imported from California through IHDP-II. A start has also been made to collect the superior strains of local mandarin from different parts of the country and propagate them vegetatively through selected rootstock. Efforts are also underway to collect the local wild chestnut to evaluate its use as a future rootstock for the improved European, Japanese and Chinese chestnuts and their hybrids.

Trials are also conducted to improve the management aspects of citrus orchards. A fertiliser trial to ascertain the right amount and right timing of application is underway. Research is also in progress to ascertain the right timing of irrigating citrus orchard. A trial is on going to determine if poor management is the cause of the declining citrus orchard at the Phuntsho Pelri Palace orchard.

Vegetables

Vegetable research for 1998-99 was focussed on a few crops as per the resolutions of the Horticulture Co-ordination meeting. With the support of the Integrated Potato Development Project, potato trials for varietal suitability were carried out both at the station and in farmers' fields. The station trial evaluated six new entries along with Desiree as the local check. Highest yield was observed in the local check followed by the entry 378015.13, which matured earlier than Desiree by 21 days. This entry will be further evaluated in farmer's fields in the rice-based system. A detailed cost-benefit study of growing tomatoes under polytunnel house for off-season production was carried out. Ratan, the variety from Bangladesh was chosen from previous year's trial for best performance for off-season production. Harvests were possible by mid March. The cash income generated in the first year would be around Nu. 8000 provided the market price does not fall below Nu. 30/kg.

Embarking into post harvest aspects of vegetables, a simple electric vegetable dryer was designed and tested in the Center. Good quality dried vegetables, particularly of chillies, brinjal, mushrooms, pumpkins etc were obtained. Demands from other Centres and interested parties led to the construction of more dryers. Off-season evaluation of a cauliflower variety from India was conducted. Pusa Deepali produced good quality curds by the end of November, while local Snowball 16 matured only after 30 days. In cabbage, variety Provati was tested for off-season production. It formed good heads but bolted early. More studies for its suitability for summer production need to be done.

The on farm trials included varietal adaptation of potato, onion and tomato in the region. Two potato entries 378699.22 and 720060 were tested at two sites ; Gaselo and Limbukha. In both the sites, the local check Desiree produced higher yield. It also matured earlier than the test varieties. Six new entries of potato were tested in a late blight hot spot area (Khotokha) for production and reaction to the disease. The three released varieties were used as checks. The entries 381379.9 and 378699.22 were found to be fully resistant to late blight. They also produced high yields of 35 and 28 t/ha, respectively. The local varieties were slightly susceptible to the disease.

Four onion varieties were tested in farmers' fields in Punakha. Red Creole produced the highest yield, followed by Arka Kalyan and Arka Niketan. Farmers preferred the varieties Arka Niketan and Arka kalyan for their medium sized uniform bulbs. In tomatoes, varieties Ratan and Pusa Sheetal were tested in two sites. Both the new varieties yielded higher than the local check Roma. Farmers preferred Ratan for its good fruits, uniform shape and acceptability to the local consumers. About six thousand asparagus crowns of variety Franklim were distributed to farmers in Gasa, Wangduephodrang and Punakha for production evaluation. Other activities included seed multiplication and production for further research, farmer's training, and germplasm tests.

LIVESTOCK

The main objective of the livestock program is to develop more productive and sustainable livestock options for wetland farmers and to strengthen crop-livestock systems research creating synergistic effect on crop production. Most of the on-station activities have been a continuation of research initiated with the start of the sector in 1993. The trial on nursery tree species was established to introduce and evaluate leguminous tree species with potential for winter fodder, green manure, weed management and soil improvement. Some of the fodder tree species under observation are *Gmelina arborea*, *Ficus cunia*, *Ficus roxburghii*, *Ficus nemoralis*, *Robinia seudoacapcia, Sesbania sp.* and *Leucaena sp*. A nursery on sub-tropical grass and legume species was established to evaluate grass and legume species for major fodder growing environments and to demonstrate these species for training purposes.

Major on-farm activities included a temperate seed mixture trial established in Phobjikha in 1996 and was monitored till May 1999. However, no proper data could be collected due to stray animals and land disputes that arose within the co-operator family. Winter fodder trial was established to find the best

combination of winter fodder mixture. Farmers were given a combination of two mixtures: Mix-1 (Oat, Hairy Vetch) and Mix-2 (Oat, Lytharus) of which Mix-2 performed better with an average biomass yield of 35.2 t/ha. Cover/fodder crops in orange orchards were established to improve the soil condition and control weed infestation. Germination of 60% in Pintoi plot and 30% in Green Leaf Desmodium was observed. These crops completely dominated and displaced the local weeds.

The sector also experimented on feeding chopped green fodder mixed with rice straw to increase the palatability and voluntary dry matter intake by the animals but this experiment showed promising results only for one year. Farmers were reluctant to adopt this as the manual chopping was laborious and time consuming. Appropriate mechanical chopping devices could help.

FORESTRY

The forestry research program of the centre focuses mainly on the social forestry sub-program. However two territorial forest management units (FMUs) have been identified to diversify into mainline forestry research in 1998.

Two forest nurseries, one each at the centre and in the Lingmutey Chu watershed are maintained. Tree saplings raised are either planted around the centre for further evaluation or in the community forestry plantation (CFP) at Omtekha and Matalumchu. A multi-purpose tree species screening trial (MPTS) superimposed on the CFP aims to assess the growth parameters of the species planted for possible screening and introduction.

In December 1998, a multi-disciplinary team conducted a participatory rural appraisal (PRA) to find out the communities perception of the present forest management by the forestry services division (FSD) and their preference for a participatory forest management for local use (PFMLU). Highlights of the PRA are in the report.

Sites for research in both the FMUs have been visited and a draft research protocol for a regeneration trial in the Khotokha FMU has been circulated for comments.

SYSTEMS RESOURCE MANAGEMENT

Farming Systems and On-farm Research

The CBNRM research which began in 1997 in the Lingmuteychhu watershed continued with the implementation of several participatory research activities on improving crop production and management, fodder for cattle, soil fertility improvement, water management, and plant protection.

Within crop management, activities were focused on understanding quantitatively the existing crop yield levels and farmer evaluation and selection of improved rice

and maize varieties. Towards winter fodder shortage oat was promoted as green fodder in a rice-oat sequence. To prevent the effect of oat on the fertility of rice soils, oat and legume mixture combination trials were also conducted. On-farm soil fertility improvement activities included improved management of inorganic fertiliser, incorporation of green manure crops, crop residue trash line to prevent soil erosion, and farmers training on crop nutrient management. The on-farm water management research continued to get better understanding of on-farm water use and water rights.

Integrated Pest Management

The IPM sector mostly provides need-based technical plant protection services to the client Dzongkhags through field visits, disease-pest verification, surveillance and monitoring. IPM research for 1998-1999 was concentrated on *Phytophthora blight* in chilli, Late blight in potato and literature reviews for *Potamogeton distinctus* in rice. The non-reliability of cultural practices to combat chilli blight has led to the initiation of resistance breeding program with assistance from AVRDC, Taiwan. The first set of Sha Ema backcross-derived resistant lines were evaluated on-station for resistance to the disease, fruit characteristics and yielding ability. Some resistance was observed in few lines but the local check was highly susceptible to the disease. None of the lines developed had the desired Sha Ema type fruit characters.

Potatoes constitute one of the major cash crops in Bhutan. Late Blight disease is the most threatening constraint in its production. Although integrated control measures are available for the major diseases, they need to be further fine-tuned. A new approach that is commonly and successfully used in South East Asia called the Farmer Field School is being tried in three potato growing areas of Phobjikha. This approach involves and educates the farmers through out the crop production process. It not only deals with the particular disease, but also gives emphasis on crop sanitation to help minimize other problems as well.

Potamogeton distinctus (Shochum) is a noxious perennial aquatic weed infesting wet lands. Mechanical weed control methods like hand weeding and rotary weeding are inefficient and expensive due to increased number of weedings. The use of herbicides however is effective. Trials conducted at RNRRC Bajo have proven that Sanbird (pyrazolate) is effective against Shochum and other weeds, but due to the unavailability of the herbicide in the country other management aspects need to be explored. A literature review was done to further understand its biology, ecology and control/management aspects.

Water Management Research

Water management research started in 1997. The WMR program has its base at the RNRRC Bajo, but has the national mandate for water management research in Bhutan. The research activities with other RNRRCs are aimed at water management research in the cultivation of perennial fruits such as apple and citrus. Within RNRRC Bajo the major research in 1998-99 was an improved water management experiment in rice using lesser water than what farmers presently use.

1 FIELD CROPS

The principal goal of this research program is to increase and sustain the productivity of cereals (rice, maize, wheat, and other minor crops), oilseeds (rapeseed-mustard, sunflower) and grain legumes (mungbean, soybean etc.). The major components of the program are integrated germplasm development, production management, and post-harvest management of the field crops. The short and medium-term objectives are to identify, adapt or develop appropriate technologies or management strategies in field crops for optimising the integrated production processes within farming systems while maintaining a sound resource and ecological base.

1.1 Integrated Germplasm Development (IGD)

The main focus of the IGD is to develop improved germplasm with high yield potential, superior grain quality, multiple resistance to major diseases and insects, and short to medium growth duration. IGD includes research activities on cereals (rice, wheat, maize, minor cereals), oilseeds, and grain legumes.

1.1.1 Rice

Attempts to improve Bhutanese rice germplasm date back to the late sixties. However, systematic and institutionalised efforts started only in 1982. The following are the major objectives of this project:

- To introduce, evaluate and recommend high yielding, improved rice varieties suitable under low to moderate input levels and at the same time responsive to higher inputs
- To improve the traditional rice varieties through breeding and selection
- To test and identify varieties suitable for different cropping patterns and for different agroecological zones.

The general methodology of assessing the performance of either introduced or locally bred varieties ensures that the entries are subject to moderate fertiliser and cultural management systems reflecting the farmers' actual practices. Seedlings are raised following semi-dry nurseries. Fields are cultivated using tractor-drawn spring tine harrow, and puddled with power tiller and levelled by planking. Seedlings are transplanted at 20 x 20cm spacing except for breeding lines where 30 x 30cm is used. Fertiliser doses applied are 70-40-20 kg NPK/ha, with half the N topdressed at PI. Weeds are controlled using Butachlor and spot weeding as necessary. Harvest and post-harvest operations are done manually.

1.1.1.1 Advanced Evaluation Trial (AET)

In 1998, AET consisted of 20 test entries including local and standard check varieties. The objective of this trial was to identify suitable varieties with high yield potential, medium height, optimum maturity and resistance to prevailing pest and diseases for mid-altitude rice valleys.

The trial was laid out in a randomised complete block design with three replications. Seedlings were transplanted in 10 sqm plots at a spacing of 20 x 20

cm. Chemical fertilizer was applied at the rate of 70:40:20 NPK kg/ha with half the N as top dress at PI. To control the weed, Butachlor 5G was applied at the rate of 1.5 kg a.i./ha. Hand weeding was done whenever necessary. Irrigation was applied as and when required. Grain yield was estimated from a harvest area of 5.04 sqm and grain moisture content was standardised at 14%. Results are presented in Table 1

Statistical analysis of grain yield showed that IR 64 was the top yielder (5.86 t/ha) although several crossbred lines such IR65239-B-B-47-B, CARD20-21-3-2-3-1-1, IR62467-B-R-B-B-1-1-B produced yields statistically comparable to IR 64. Local check Zakha was the lowest yielding variety (3.82 t/ha) among the entries. Occurrence of insect pests and diseases was negligible during the test season and hence no intervarietal rating was done. Two to four best performers from this trial will be evaluated in the farmers' fields in the ensuing season.

Table 1 Yield and agronomic traits of entries in AET

Variety	Yield (t/ha)	P.ht (cm)	50% Flw (days)	Maturity (days)
IR 64	5.86	86	119	151
IR65239-B-B-47-B	5.83	108	120	152
CARD20-21-3-2-3-1-1	5.47	109	119	152
IR62467-B-R-B-B-1-1-B	5.46	99	102	136
IR61331-2-25-2-3-1-1	5.46	102	119	151
CARD21-15-3-2-3-3-2-B	5.42	104	103	137
IR62467-B-R-B-60-B	5.41	128	111	143
IR62467-B-R-B-50-3-B	5.23	99	111	143
CT9145-4-21-1-1	5.09	110	120	152
CARD20-21-3-2-3-2-B	5.03	107	119	152
CARD21-15-2-1-3-1-3-B	4.87	114	102	136
IR62467-B-R-B-10-B	4.76	105	111	143
IR60133-184-3-2-2-2	4.69	110	120	153
CARD21-14-1-1-3-3-B	4.50	111	106	138
IR65239-B-B-50-B	4.48	111	120	152
IR62473-B-R-B-15-B	4.48	111	102	136
CARD21-15-14-1-2-2-2	4.43	115	108	139
IR62745-B-R-B038-B	4.36	108	108	141
BKNB5073-16	4.17	88	121	153
ZAKHA LOCAL	3.82	114	118	150
CV%	11.8	14.9	1.5	0.9
S.E.D.	0.48	13	1	1

1.1.1.2 Initial Evaluation Trial (IET-1)

Two sets of IETs were established, composed mainly of breeding lines, to select the most promising lines/varieties in terms of grain and straw yields, maturity, height and resistance/tolerance to biotic and abiotic stresses.

IET-1 was laid out in a randomised complete block design with three replications. Seedlings were transplanted in 10 sqm plots. Chemical fertilizer was applied at the rate of 70:40:20 NPK kg/ha, with half the N top dressed at PI. Butachlor 5G was applied at the rate of 1.5kg ai/ha to control weed pressure. Hand weeding and irrigation was done whenever necessary. Grain yield was obtained from a

harvest area of 5.04 sqm. ANOVA was used to analyse the data and the results are presented in Table 2.

Analysis showed that several test varieties produced significantly higher grain yields than the local check variety Zakha. However, none of the entries could perform better than IR 64. Days to 50% flowering ranged from 103-120 days. Likewise, plant height ranged from 84-125 cm. No significant damage due to insects and diseases occurred precluding a differential rating among the entries. The elite selection from this trial will be further evaluated in the following season.

Table 2 Grain yield and characters of entries in IET-1

Variety	Yield (t/ha)	P.ht (cm)	50% Flw (days)
IR 64	5.59	84	119
IR47310-16-2-2-2	5.22	85	105
IR62467-B-R-B-8-B	5.10	121	107
IR60829-50-1-1-3	5.08	85	120
IR62473-B-R-B-12-B	4.88	114	112
IR62467-B-R-B-52-B	4.81	131	109
IR6332-B-B-B-26-B	4.80	108	107
IR62467-B-R-B-29-B	4.74	118	105
ZAKHA LOCAL	4.73	117	119
IR63332-B-B-B-25-B	4.67	113	107
IR62473-B-R-B-3-B	4.60	121	109
IR62745-B-R-B-5-B	4.57	114	109
IR62467-B-R-B-1-B	4.56	125	107
IR62467-B-R-B-44-B	4.46	123	108
BATANG SUMANI	4.45	91	119
BR1067-84-1-3-2-1	4.43	86	116
IR62467-B-R-B-41-B	4.39	109	107
IR63332-B-B-B-3-B	4.17	109	103
IR56383-35-3-2-1	4.17	80	107
IR62156-138-3-3-2-2-2	3.99	78	107
IR62467-B-R-B-66-B	3.82	121	105
IR62745-B-R-B-18-B	3.78	92	112
CV%	10.8	6.5	2.1
S.E.D.	0.41	6	2

1.1.1.3 Initial Evaluation Trial (IET-2)

Composed of elite breeding lines, IET-2 aimed to select promising lines in terms of grain and straw yields, maturity, height, grain quality and resistance to biotic and abiotic stresses.

The trial was laid out in an RCBD with three replications. Seedlings were transplanted in straight rows at spacing of 20 x 20cm in 10 sqm plots. Chemical fertilizer was applied at the rate of 70:40:20 NPK kg/ha. Butachlor 5G was applied at the rate of 1.5kg a.i./ha to control weeds. Hand weeding and irrigation was done whenever necessary. Grain yield was obtained from 5.04 sqm.

Analysis of variance was used to detect differences among the varieties. Results in Table 3 showed that IR62467-B-R-B-34-2B, a cross between Attey and

Suweon 358 produced the maximum yield of 5.97 t/ha. Several other breeding lines also produced significantly higher grain yields than the local check variety Zakha. All the the breeding lines have genes from local varieties in their pedigree. Some of the lines matured slightly earlier than IR 64 and were much taller in plant height. No significant insects and diseases were observed among the entries. Selections from this trial will be further evaluated.

Table 3 Grain yield and other traits of entries in IET-2

Variety	Yield (t/ha)	P.ht (cm)	50% Flw (days)
IR62467-B-R-B-34-2-B	5.97	121	120
IR 64	5.48	86	119
IR62472-B-B-50-B	5.44	112	119
IR62467-B-R-B-73-1-B	5.12	123	118
IR65239-B-B-13-1-B	4.94	114	117
ZAKHA LOCAL	4.93	120	120
IR62467-B-R-B-64-1-B	4.83	124	112
IR62470-B-R-B-14-1-B	4.80	114	112
IR62467-B-R-B-63-1-B	4.76	125	110
IR62467-B-R-B-6-1-B	4.67	120	107
IR62470-B-R-B-14-2-B	4.64	124	112
IR62472-B-B-1-B	4.62	93	119
IR65239-B-B-17-B	4.39	103	120
IR62473-B-R-B-30-1-B	4.32	112	108
IR62470-B-R-B-12-B	4.25	126	106
IR65239-B-B-37-B	4.08	111	121
IR62470-B-R-B-28-B	3.96	116	111
IR62472-B-B-14-B	3.95	105	107
IR62467-B-R-B-4-2-B	3.91	114	116
IR62473-B-R-B-20-1-B	3.08	121	110
IR62745-B-R-B-16-1-B	2.85	114	101
CV%	13.1	9.5	1.8
S.E.D.	0.48	9	2

1.1.1.4 Observation Nursery I

Breeding (pedigree) lines from different populations were evaluated in single plots of 10 sqm for yield, maturity period, pest resistance and plant height. Seedlings were transplanted at a spacing of 20 x 20 cm in late June. Inorganic fertilisers were applied at the rate of 70: 40: 20 NPK kg/ha. Butachlor was applied at the rate of 1.5 kg a.i./ha to control weeds.

The performance of selected entries is presented in Table 4. The observed yield ranged from 3.60-8.41 t/ha. The yields of most of the entries were higher than the local check variety Zakha. Maturity ranged from 138-154 days, while the plant height ranged from 81-133 cm. No notable insect pests and diseases were observed in the trial. The selected entries will be further evaluated in replicated yield trials.

Table 4 Agronomic traits of entries in Observation Nursery I

Varieties	50% Flw (days)	Maturity (days)	Plant height (cm)	Grain yield (t/ha)
IR62467-B-R-B-24-1-B	107	148	105	6.57
IR62467-B-R-B-34-3-B	116	153	93	6.33
IR62467-B-R-B-F60-1-B	105	143	81	6.41
IR62467-B-R-B-F49-1-B	117	154	91	5.68
IR62467-B-R-B-4-3-B	108	145	93	4.76
IR62467-B-R-B-13-1-B	108	145	84	6.22
IR62467-B-R-B-35-3-B	117	153	110	4.06
IR62467-B-R-B-69-2-B	101	138	119	4.67
IR62467-B-R-B-49-3-B	117	154	123	5.75
IR62467-B-R-B-F8-1-B	105	142	104	5.75
IR62467-B-R-B-35-2-B	112	149	117	4.35
IR62470-B-R-B-82-2-B	108	146	122	3.85
IR62470-B-R-B-86-1-B	106	146	126	4.10
IR62470-B-R-B-86-2-B	107	146	123	4.26
IR62473-B-R-B-30-3-B	108	146	118	6.09
IR62473-B-R-B-F17-1-B	104	143	80	6.94
IR62473-B-R-B-30-2-B	109	146	92	6.76
IR62473-B-R-B-24-2-B	117	154	110	5.80
IR62473-B-R-B-16-3-B	117	154	133	6.22
IR62745-B-R-B-20-1-B	105	142	103	4.61
IR65239-B-B-7-1-B	117	153	84	6.48
IR62745-B-R-B-5-1-B	109	147	85	4.90
IR65239-B-B-68-1-B	117	154	122	7.54
IR62472-B-B-61-1-B	122	157	102	4.71
IR62472-B-B-58-1-B	102	139	123	3.60
IR62472-B-B-60-1-B	105	142	97	3.95
IR62745-B-R-B-32-1-B	104	142	118	3.60
IR62472-B-B-31-1-B	122	157	115	6.08
IR62472-B-B-39-1-B	109	146	118	5.08
IR 64	111	147	88	8.41
ZAKHA LOCAL	113	150	132	5.27

1.1.1.5 Observation Nursery II

In Observation II, 18 varieties introduced from the Yunan province of China were evaluated in single plots of 10 sqm for yield, maturity period, pest resistance and plant height. Seedlings were transplanted at a spacing of 20 x 20 cm in the first week of June. Inorganic fertilisers were applied at the rate of 70: 40: 20 NPK kg/ha. Butachlor was applied at the rate of 1.5 kg a.i./ha to control weeds.

The performance of the entries is presented in Table 5. Grain yield ranged from 2.64-4.56 t/ha, which was generally low. Maturity ranged from 131-149 days from sowing, while the plant height ranged from 71-141 cm. Tight shattering was observed in most entries. No notable insect pests and diseases were observed in the trial. Selected entries will be further evaluated in replicated yield trials.

Table 5 Yield and agronomic traits of entries in Obs. Nursery II

Varieties	50% Flw (days)	Maturity (days)	Plant height (cm)	Grain yield (t/ha)
KUNGEN 217	102	138	104	3.57
YUNLEN 16	95	132	79	2.64
YUNLEN 18	93	131	95	3.57
YUNLEN 10	107	143	137	3.74
KUNMING 830	99	143	113	3.53
YUNLEN 9	102	138	117	3.81
YUNLEN 20	113	149	121	4.21
YUNLEN 5	101	138	94	4.56
YUNLEN 13	100	135	103	3.00
YUNLEN 11	113	149	118	3.37
YUNLEN 8	109	145	117	3.29
YUNLEN 1	107	143	89	2.64
YUNLEN 7	105	141	114	3.41
YUNLEN 4	95	141	104	3.32
YUNLEN 6	128	134	141	3.21
YUNLEN 17	95	132	95	3.90
YUNLEN 12	108	144	141	3.57
MYOKO KOGEL WASE	91	-	71	-
NO. 11	93	129	90	2.67
CHUMMRO	107	143	143	2.90

1.1.1.6 Observation Nursery III

In Observation III, another set of introduced Chineses varieties were evaluated in single plots of 10 sqm for general adaptability under Bhutanese conditions. Seedlings were transplanted at a spacing of 20 x 20 cm in early June. Inorganic fertilisers were applied at the rate of 70: 40: 20 NPK kg/ha. Butachlor was applied at the rate of 1.5 kg a.i./ha to control weeds.

The performance of selected entries is presented in Table 6. Grain yield ranged from 2.00-4.36 t/ha. The varieties are typically Japonicas with bold non-shattering grains unlike the Bhutanese varieties that are mostly intermediates between Indicas and Japonicas. Maturity ranged from 131-164 days, while the plant height ranged from 74-115 cm. No notable insect pests and diseases were observed in the trial.

1.1.1.7 Observation Nursery IV (IRFAON)

This nursery consisted of 60 varieties and breeding lines from the International Rice Fine Grain and Aromatic Observation Nursery (IRFAON) of IRRI. It was a collaborative attempt to identify entries with desirable grain types and aroma that could be utilised directly as varieties or as donors in breeding programs. Seedlings were transplanted at a spacing of 20 x 20 cm in the first week of June. Inorganic fertilisers were applied at the rate of 70: 40: 20 NPK kg/ha. Butachlor was applied at the rate of 1.5 kg a.i./ha to control weeds.

The performance of the selected entries is presented in Table 7. Grain yield ranged from 3.10-7.48 t/ha. Most of the varieties were scented. No notable insect

pests and diseases were observed in the trial. Selected entries will be further evaluated in replicated yield trials.

Table 6 Yield and agronomic traits of entries in Obs. Nursery III

Varieties	50% Flw (days)	Maturity (days)	Plant height (cm)	Grain yield (t/ha)
HEYN-NO	101	137	83	3.70
PEINGZONG	109	144	88	2.00
GUICHO-2	128	134	87	4.01
CHINA-6	128	134	95	2.49
HEXI-24	109	144	90	4.30
CHINA-7	98	134	88	2.87
TAO-YIN	128	164	93	2.44
GUCHIO-2	128	163	83	4.30
CHINA-1	128	163	82	4.36
TAO-IN	159	164	74	3.77
CHINA-8	95	132	87	2.70
CHINA-2	97	134	86	2.28
CHINA-3	128	134	93	4.35
CHINA-5	128	134	94	3.76
XINGYUN COUNTRY	93	130	92	3.05
CHINA-4	98	134	115	3.08
LOCAL	98	136	84	2.10
NO.11	95	131	91	2.67
CHUMMRO	104	140	117	3.17

1.1.1.8 Observation Nursery V (IIRON)

It consisted of 100 varieties and breeding lines from the International Irrigated Rice Observation Nursery (IIRON) of IRRI, as part of the collaborative exchange of elite lines and varieties from the world's rice improvement program and the initial evaluation under a wide range of irrigated rice environments. Thirty three day-old seedlings were transplanted at a spacing of 20 x 20 cm in the first week of June. Inorganic fertilisers were applied at the rate of 70: 40: 20 NPK kg/ha. Butachlor was applied at the rate of 1.5 kg a.i./ha to control weeds.

Grain yield (Table 8) ranged from 2.06-9.08 t/ha; plant height from 85-122 cm and days to 50% flowering from 102-137. No notable insect pests and diseases were observed among the genotypes. Selected entires will be further assessed.

1.1.1.9 Observation Nursery VI (IRHON)

This nursery comprised of 33 hybrids, 9 maintainers, 29 restorers and check varieties, as part of the collaborative INGER network of IRRI that aims to conduct preliminary evaluation of elite rice hybrids and their parental lines under a wide range of irrigated rice environments. Thirty-five day-old seedlings were transplanted at a spacing of 20 x 20 cm in the first week of June. Inorganic fertilisers were applied at the rate of 70: 40: 20 NPK kg/ha. Butachlor was applied at the rate of 1.5 kg a.i./ha to control weeds.

The performance of the entries is presented in Appendix 1. The highest grain yield of 9 t/ha was obtained from IR73409H and the lowest (1.25 t/ha) from IR65514-96-1-1-3R. Plant height ranged from 72-113 cm and days to 50% flowering from 98-1139. This was the first time that any rice hybrids were grown in the kingdom but there are no immediate future plans for their promotion.

Table 7 Grain yield and other traits of entries in IRFAON

Varieties	50% Flw (days)	Plant height (cm)	Grain yield (t/ha)	BRS*
CNT87040-33-1-1	121	93	3.17	9
CNTLR85033-9-3-1-1	110	104	5.93	5
CNTLR85093-47-2-1-1	121	97	6.10	5
DELLA	103	117	4.77	1
DM24	127	86	3.52	1
DOM SOFOOD	103	140	3.79	1
DR92	117	83	7.48	1
FRX14F3B-14F6BF7	121	93	5.12	1
FRX92F3B-14F4BF5	121	79	7.15	5
GAN-WAN-XIAN 22	104	82	5.46	1
HASSANY	86	107	2.14	5
HEI BAO	83	64	3.55	1
IR62898-286-6-1	148	82	3.17	1
IR65638-169-3-2	104	81	5.51	1
IR65638-91-1-1	103	115	4.93	1
IR66229-45-3-2	110	106	3.52	1
IR66231-106-1-2	97	82	5.52	1
IR66231-127-1-3	97	82	5.22	1
IR66231-262-1-3	97	86	5.28	1
IR66231-96-3-3	104	84	5.51	1
IR66232-75-5-1-2	96	90	4.14	5
IR66298-5-3-3-2-1	122	122	4.00	5
IR66696-49-1-2	100	88	3.55	1
IR67013-58-1-2	100	89	5.33	1
IR67410-174-1-2-1	104	85	4.43	1
IR67414-168-3-3-2	121	89	5.86	1
IR67415-272-3-4	108	78	5.86	1
IR67417-2-1-6	121	83	4.87	1
IR67418-100-2-1	103	84	4.09	1
IR67418-20-3-1-3-1	109	118	3.52	1
IR67420-206-1-2-3-2	121	107	4.27	1
IR67420-218-1-5-1	103	90	5.44	1
IR67894-40-1	121	120	3.87	1
PK3161	104	106	5.23	1
PK4553-42-1-1	127	88	3.10	1
SR6014-ZHONSHI 4	109	92	5.23	1
T3	127	80	5.99	1
BASMATI 370	108	105	5.40	1
KASHMIR BASMATI	101	110	6.88	1

* BRS = Brown rice shape using SES scale

Table 8 Performance of entries in IIRON

Designation	50% FLW days	Plant Ht. Cm	Grain yield T/ha
SPR85163-5-1-2-4	119	112	9.08
IR45138-131-2-1-1-3-1	102	93	7.86
IR 72	106	88	8.85
M 88	119	106	5.73
SPR88090-30-1-2-4	119	88	7.26
ITA222	119	94	7.41
VX83	125	122	5.23
NR11	105	87	7.60
RP1667-301-1196-1562	107	93	4.80
SPR85089-2-1	120	114	5.93
PSL85048-19-3-1-1	126	94	7.64
IRGA318-11-6-9-2	101	88	4.37
RP2240-86-84	137	93	3.58
IR58185-23-3-3-1	125	95	4.44
X21	108	85	7.40
CT61163-8-9-5-2-M-27-M	119	85	5.79
RHS330-25-CX-3CX-4CX-OZA	119	105	6.83
CT8240-15-3P-21-11-21	115	101	4.81
X20	146	88	7.21
PSB RC2	120	95	6.95
RP2235-63-42-7	115	99	7.95
NAR 15153-4-3	106	106	5.29
MIANXING7	119	100	5.73
ALTO MAYO 88	125	95	2.06
BR4829-28-2-4	120	113	6.47
ZHONGYU 5	110	101	6.22
SPRLR81047-60-2-2	118	94	3.94
CT9497-4-3-1-1-M-4-3P-M	125	106	6.26
NANJING 14	108	99	6.54
IR55558-50-2-3-3-2	120	88	6.34
IR 64 (check)	108	92	6.37
LOCAL ZAKHA	110	122	5.48

1.1.1.10 Observation Nursery VII (IRBN)

IRBN comprised of 184 entries received from INGER, IRRI with the primary aim of evaluating the varietal reaction of selected varieties and breeding lines against diverse populations of the fungus *Pyricularia grisea.* Seedlings were transplanted at a spacing of 20 x 20 cm in the first week of June. Inorganic fertilisers were applied at the rate of 70: 40: 20 NPK kg/ha. Butachlor was applied at the rate of 1.5 kg a.i./ha to control weeds.

The performance of the entries in terms of leaf and panicle blast is shown in Appendix 2. Leaf blast scores ranged from 0 to 7, with most entries scoring none or very slight infection. Likewise, panicle blast scores were from 0 to 9. The local check Zechum was completely infected with panicle blast.

1.1.1.11 Pre-production Evaluation Trial (PRET)

On-farm evaluation of station-tested, promising varieties is a regular technology verification activity of the centre. The objective of such experiments is to identify suitable location-specific varieties under farmers' management levels. PRET is a replicated and researcher-supervised onfarm trial.

Four improved lines were tested against the local variety in six locations in Matalungchu and Upper Gaselo (Table 9). The analyzed results indicated that H2O2-7-1-1-1, an Argentine line, produced the highest yield of 4.89 t/ha, averaged across locations. IR56346-1-1-2-1-9-1-1, a cross between Wangdu Kaap and BG90-2, did well outyielding the local Tan Tshering by 0.83 t/ha. Location-wise yield averages indicated differences among the test locations, reflecting variations in micro-climatic and management practices. The three sites in Upper Gaselo were more productive than the other three in Matalungchu.

Table 9 Performance of entries in PRET in Punakha-Wangdue valley

	L O C A T I O N S						
Varieties	1	2	3	4	5	6	Mean
H2O2-7-1-1-1	4.76	3.95	3.23	6.42	3.86	7.11	4.89
IR56346-1-1-2-1-9-1-1	3.72	4.69	3.71	5.15	5.02	6.32	4.77
LOCALS	2.48	3.96	4.34	5.21	3.12	4.52	3.94
CARD21-14-1-1-3-2-1-B	3.94	3.22	3.50	4.46	2.83	4.24	3.70
CARD21-15-3-2-3-2-3-B	3.82	2.45	3.75	3.78	2.26	4.46	3.42
Location Mean	3.74	3.65	3.71	5.00	3.42	5.33	-

CV% 18
S.E.D 0.43
Location 1-3 : Matalungchu; 4-6 : Upper Gaselo
Local variety : Tan Tshering

1.1.1.12 Production Evaluation Trial (PET)

About two kg seeds of five promising crossbred lines were distributed through the extension to farmers in Punakha-Wangdue valley. The main aim of this activity was to evaluate the lines under farmers' actual field conditions and management practices. There were five test locations in Wangdue and seven in Punakha. Most of the farmers used semi-dry to dry nursery methods to raise their seedlings. Seed sowing was done in April-May and transplanting took place from May to July. FYM was the major nutrient input basally while most farmers used nitrogen for topdressing. Butachlor and handweedings were used as weed control measures.

In most of the locations the test variety performed better than the local varieties. In Punakha, CARD21-10-1-1-3-2-1 yielded highest (7.61 t/ha) averaged across locations compared to 5.72 t/ha for the locals (Table 10). On an average, the improved test lines yielded 1.42 t/ha higher than the local varieties. In Wangdue, the highest yielding line was IR61331-2-25-2-3-2-2 (7.28 t/ha), which is a cross of Paro Maap and IR41996-. Depending on the acceptability of the test materials, farmer-collaborators maintain seeds of the varieties they like (Table 12) and even distribute or sell to their neighbours, thus adding to the onfarm varietal diversity. Farmers' feedback indicates that many wanted to maintain seeds provided in 1998 for the following crop season.

Table 10 Performance of selected varieties in PET in the Punakha valley.

Variety	Chubu	Zomi	Guma	Tewang	Kabji	Mean
IR61331-2-25-2-3-2-2	6.41	5.12	10.48	5.83	-	6.96
IR61331-2-148-B	7.46	6.05	9.23	8.65	5.96	7.47
CARD21-10-1-1-3-2-1	-	6.66	10.45	6.78	6.54	7.61
CARD21-14-1-1-3-2-1-B	6.18	6.82	6.43	6.41	5.52	6.27
IR61328-136-2-1-2-3	-	7.38	8.48	7.13	6.50	7.37
LOCALS	5.35	5.50	5.86	6.04	5.84	5.72
Local names	Botoli	Yankum	Kaap	Maap	Dungchem	

Table 11 Performance of selected varieties in PET in the Wangdue valley.

Variety	Adang	Kashi	D/Uma	Bjena	F/yul	Nisho	Gaselo	Mean
IR61331-2-25-2-3-2-2	7.53	6.77	-	7.29	-	7.72	-	7.28
IR61331-2-148-B	-	6.07	-	-	-	-	7.35	6.71
CARD21-10-1-1-3-2-1	-	6.59	-	5.30	7.16	-	-	6.35
CARD21-14-1-1-3-2-1-B	4.43	-	2.87	-	-	4.19	-	3.83
IR61328-136-2-1-2-3	-	-	-	6.95	6.98	-		6.97
LOCALS	6.23	3.43	4.55	-	-	-	5.56	4.95
Local names	Maap	Maap	Zakha	-	-	-	Tantshering	

Management practices

Seed sowing:	April 14 – May 28, 1998
Transplanting:	May 5 – July 25, 1998
FYM:	All sites ranging from 150-1400 kg per acre
Topdress:	Majority of the sites; 2-4 kg per langdo
Weed control:	Handweeding 2 times; Butachlor 10-12 kg per acre
Preference:	Almost all farmers keeping some amount of seeds for planting again.

Table 12 Farmer collaborators of PET 1997 who grew some entries in 1998 on their own accord

Farmers	Village	Geog	Variety	Area	Remarks
Lham	Lawakha	U Gaselo	IR61328-8-136-2-1-2-3	0.5 langdo	Cooking and milling quality like locals.
Dorji	Chendegang	Guma	-----do-----	1.5 langdo	Cooking and milling quality like local Botoli.
Zekhu	Sirigang	Kabji	-----do-----	1 langdo	----do----
Daw	Thangu	Thetsho	-----do-----	1 langdo	----do----
Cheni	Chungsika	Phangyul	CARD21-10-1-1-B	3 langdo	Had kept all grains as seeds; like locals.

1.1.1.13 Seed Increase for Research

To make seeds readily available for research purposes, both on-station and on-farm, the Centre routinely multiplies seeds of released varieties as well as the

emerging new varieties. Nucleus seeds of released and promising varieties are also being maintained. Varieties and their quantity of seeds multiplied are presented in Table 13.

Table 13 Rice Seed Maintenance and Production

Sl No.	Variety	Quantity (Kg)
1.	CARD 21-15-3-2-3-B	117
2.	IR 64	1020
3.	NO 11	151
4.	CHUMRO	130
5.	IR 61331-2-25-2-3-2-2	280
6.	H202-7-1-1-1	172
7.	IR56346-1-1-R-1-9-1-1	130
8.	MILYANG 54	300
9.	IR 66512-B-38	130
10.	IR 66408-B-9-2	34
11.	IR 66412-B-36-2	152
12	IR 66412-B-30-3	160
13.	CARD 21-10-1-1-3-2-1	645
14.	IR 61328-136-2-2-1-2-3	264
15.	IR 61331-2-148-B	451
16.	CARD 21-14--1-1-3-2-B	365
17.	T-23	53
18	K. BASMATI	46

1.1.1.14 Collection and Conservation of local rice germplasm

Collection, characterisation, preservation, and rejuvenation of rice germplasm are considered as important activities in varietal development for higher yield and as sources of resistance to abiotic and biotic stresses. Germplasm are also an invaluable resource for sustainable food production in the future. In 1998 a total of 154 local rice varieties from different altitudes were rejuvenated and characterised at the station (Appendix 3).

1.1.2 Wheat

The wheat research program suffered a slight setback due to the unavailability of germplasm for further research and evaluation. Efforts are underway to establish formal links with the wheat research institutes in the SAARC countries, notably India and Nepal, so that new test materials could be accessed on a regular basis. The decrease in wheat research is also attibuted to the fact that the major wheat research has been shifted to RNRRC Jakar, which is the focal centre for the improvement of wheat, barley and other secondary cereals.

In 1998-99 season, seed multiplication of the released varieties was a major activity at the Center.

1.1.3 Grain Legumes

1.1.3.1 Groundnut Variety Trial

Groundnut is a premier oilseeds crop of the neighbouring countries like India and China. It contributes nearly 40% of the total oilseeds production in the world. However in Bhutan, due to lack of appropriate oil extraction setup, it is not cultivated on a large scale. Farmers grow in small pockets mostly for local consumption in various forms. The straw after harvest can be fed to cattle. This trial was conducted mainly to select suitable and high yielding varieties of groundnut.

The trial was laid out in an RCBD with 3 replications. One to two kernels per hill at a distance of 15-20 cm apart were sown in shallow furrows 30 cm apart, in plots of 3 sqm. About 5t/ha FYM and 20:40:0 NPK Kg/ha was applied basally and 10 kg N/ha was topdressed after the 1st irrigation. The crop was sown in the second week of April. Single irrigation was given 34 DAS. A second weeding was done 30 days after the first weeding. Harvesting was done from the 2nd week of October until third week of November.

Table 14 Kernel and pod yield of test varieties

Varieties	Kernel yield t/ha	Pod yield t/ha	DAM	Rust 0-5
ICCGV 86699	1.92	4.23	220	4
ICCGV 86155	1.18	2.59	220	4
ICGV 86158	1.15	2.40	180	2
ICGV 87378	1.26	2.62	180	3
ICGV 87921	1.55	3.65	180	3
KADIRI	2.00	4.29	220	4
CV%	14	16		
S.E.D.	0.17	0.44		

Rust scoring based on visual observation: 0 - none and 5 - most affected

Table 14 shows that higher yielding varieties are longer duration and tolerant to rust. Observations made 120 DAS showed that all varieties were infected by rust. However after 30 days the short duration varieties were harvested.

Harvesting of these early varieties coincided with the peak season of rice harvesting in the Wangdue-Punakha valley. The late varieties were harvested after the rice harvest.

Groundnut in Bhutan may have potential for growing on a small scale, in the kitchen garden, or intercrop with maize in the dryland for local consumption. It may be recommended in the low and mid-maize growing pocket areas. For Wangdue– Punakha valley late varieties are suitable as they could be harvested after rice season and yields are also high. The straw of these late varieties were still green at the time of harvest, which can be fed to cattle. The following varieties have been chosen for further evaluation: ICGV 86699, ICGV87921 and Kadiri.

1.1.3.2 Soybean Variety Trial

Farmers grow soybeans in dryland, sometimes intercropped with maize. Some farmers in the southern parts also grow them on rice bunds and terrace walls. Grains are used in various ways. Green pods are boiled and seeds eaten, and the dried grains are roasted and eaten. Sometimes farmers also grind, boil and ferment the beans for food. Besides grain yield farmers are also aware of its advantage on improving soil fertility. The objective of this trial was to compare some improved varieties with the local and select check varieties.

The trial was conducted in an RCBD with 3 replications. A plot size of 20 sqm (5mX4m) was used. Seeds were sown at a distance of 5cm plant to plant in rows of 40 cm apart. Fertilizers used were 20:60:0 NPK kg/ha. Sowing was done in the 1st week of June. A light weeding was given after 30 days of sowing. No irrigation was provided at all. There were no major pest and disease problems.

Table 15 Yield and other traits of soybean varieties

Variety	Grain yield	DTM	Bio-mass	Grain colour/character
BRAGG	1.77	102	Moderate	White medium size
AGS 313	1.62	102	Moderate	Greenish small size
AGS 327	1.93	108	Moderate	White medium size
AGS 258	1.97	108	Moderate	White medium size
One Daughter	1.64	102	Less	Green big (veg soybean)
AGS 286	1.35	108	Moderate	Greenish small size
Local Tsirang(red)	1.77	122	More	Reddish medium size
Local Nabji(red)	1.27	122	More	Reddish medium size
CV%	7.5			
SE.D	0.10			

All the improved varieties matured earlier compared to the locals (Table 15). Total biomass was more from the local varieties, however when nodulation was checked, more reddish nodules were present in the improved. Some of the varieties (AGS 313, AGS 286, AGS327) were evaluated in the Limbuteychu Watershed, of which AGS 286 and AGS 327 had positive feedback (early

maturity and good taste) from the farmers. Promising materials will be further evaluated in farmers' fields, including Tsirang and Dagana in the future.

1.1.3.3 Mungbean Variety Trial

Mungbean is popularly grown in the southern and eastern parts of the country. It is consumed as *dal* together with rice. The crop residues and the husk can be fed to cattle. Since it is a leguminous crop it also improves soil fertility. Farmers realise its benefit of improving soil texture when inter-cropped with maize. The aim of this trial was to select suitable varieties of mungbean from amongst introductions from AVRDC.

The trial was laid in RCB design with 3 replications, in a plot size of 3m X4m with a spacing of 40 cm row to row and 5-10 cm plant to plant. Fertilizer was applied at the rate of 20:60:20 NPK Kg/ha as basal dose. Seeds were sown in the 1st week of August and harvested in the last week of October. A light weeding was given after 30 days of sowing. Thinning was done to maintain proper spacing 15 days after germination. The crop was grown under rainfed condition.

Grain yields are comparatively low (Table 16). VC 6173 lines showed better performance. The yield of local variety was the highest, but VC lines matured earlier. They matured 80-90 DAS, whereas local variety took 100-120 DAS. As mungbean is very sensitive to waterlogging and since they were sown in rice land the crop did not do very well.

Table 16 Grain yield (t/ha) of mungbean varieties/lines

Variety	Grain yield	PM score
VC – 6173B-13	0.777	1
VC – 6173-33	0.891	0.5
VC – 6173B-6	0.720	0.5
VC – 6153B-20P	0.550	1
VC - 6370 – 92	0.637	0.5
VC - 6141 – 90	0.773	2
VC – 6173B – 10	0.943	1
VC – 6141 – 96	0.747	0.5
VC – 6144B – 12	0.447	1
LOCAL (Check)	1.340	0
CV%	22.8	
S.E.D	0.145	

PM Score : Powdery Mildew scoring
0 = immune
5 = highly susceptible

1.1.3.4 Mungbean Observation Trial

In this trial, 20 mungbean lines were tested in a plot size of 2m X 2m with a spacing of 40 cm row to row. Seedlings were thinned 15 days after germination to

maintain a spacing of 5-10 cm between plants. Fertiliser at the rate of 20:60:20 NPK Kg/ha as basal dose was applied. The trial was completely under rainfed condition. The seeds were sown in lines in the 1st week of August and harvested in last week of October.

The yields are very encouraging, ranging to as high as 3.75 t/ha (Table 17). The terrace had well drained and friable soils, resulting in good yield. The best selected entries will be further more evaluated in the station before they are taken on-farm. Powdery mildew infection was negligible.

Mungbean is a very sensitive legume crop. Its cultivation in wetland is difficult. It requires well drained friable soil. However, varietal trial so far have been done in wetlands. In some of the terraces, drains were prepared to avoid water logging. The yield difference in the above two trials is evidence to the fact that mungbean requires well drained soils. The introduced varieties are early maturing. Sequential sowing trials to determine optimum sowing times could be done once suitable varieties are identified.

Table 17 Yield performance of mungbean lines in Observation Nursery

Variety	Grain yield (t/ha)
VC 6144 (47–28–2)	3.00
VC 6148 (59 – 12)	3.00
VC 6153 B – 19	1.75
VC 6173 B – 11	2.50
VC 6173 B – 14	2.25
VC 6375 (41 – 13 – 6)	3.25
VC 6379 (23-11)	2.50
VC 3960 A – 88	3.25
VC 3960 – 89	2.75
VC 6370 (30-65)	3.25
VC 6173A	2.00
VC 6173 C	3.25
VC 6371 – 93	2.25
VC6368 (46-40-4)	2.62
VC6369 (53-97)	3.00
VC6368(46-7-2)	2.50
VC 6371 –94	3.00
VC 6372 (45-8-1)	3.75
VC 6372 (45-8)	2.62
VC 6367 (44-55-2)	2.62

1.2 Crop Production Management

1.2.1 Rice Yield Potential Trial

Current fertiliser recommendations for rice are low to moderate reflecting the inaffordability of chemicals by farmers and subsistence-dominant farm economics. However, scope exists for increased fertiliser use as rice productions becomes increasingly commercialised. The objective of this trial was to try and achieve the maximum potential rice output using a higher dose of N fertiliser (150:40:20 NPK Kg/ha) and FYM (14t/ha) combined with recommended management practices.

The trial was set up in RCB design with 3 replications. A plot size of 5mX3m and a spacing of 20cm X20cm was used. One-month old seedlings of 10 released and pre-release rice varieties were transplanted. Butachlor 5G @ 2kg a.i./ha was applied after 3 days after transplanting. Fertilizer was applied in 3 splits; 70N, 40P, 20K kg/ha was applied basally; 40N kg/ha was applied as topdressing during tillering and 40N kg/ha during flowering. Recommended management practices were followed.

The results in Table 18 showed that IR 64 produced the highest grain (9.07 t/ha) and straw (14.8 t/ha) yields amongst all the test entries. The high fertility regime inversely affected the performance of Chumro and No.11, which are in fact not recommended as main crop varieties in the mid-altitude rice areas. Chumro and IR61331-2-25 had few panicles with empty grains; panicle blast, sheath blight and sterility were observed. The level of infection however was not very high. Chumro also lodged badly causing difficulty in harvesting.

Table 18 Grain and straw yields of released and pre-release rice varieties

Variety	Grain yield t/ha	Straw yield t/ha
IR 64	9.07	14.8
CARD 21-14	8.89	10.9
IR 61331-2-148	7.98	11.3
M 54	7.82	11.7
CARD 21-10	7.53	11.3
IR 20913	6.41	12.6
IR 61331-2-25	6.37	9.5
IR 61328	5.88	12.3
NO. 11	3.72	9.1
CHUMRO	3.40	11.6
CV %	5.8	11.7
S.E.D	0.31	1.1

Most varieties seemed to respond to higher fertilisation. However, appropriate combinations of macro-nutrients need to formulated and tested again.

1.2.2 Effective Micro-organism (EM) activities

With resource and time limitations, EM activities were carried out only in the station as Nature Farming Demonstration, where cereals, fruits, and even a few trees are raised. Growing vegetables was also in the plan, but it would be initiated only after improving the present irrigation system.

The Nature Farming Demonstration was started in 1995. Crop cultivation is done using only organic matter such as Farm Yard Manure, EM Bokashi and EM solution. Organic farming is currently tried on rice, wheat, mustard and maize.

Rice

The total area covered by rice cultivation is about 5800 sqm. The variety grown is IR 64. The field is ploughed 3 weeks before transplanting. It is puddled after applying 7t/ha of EM Bokashi and kept for 2 weeks. FYM 5t/ha is applied before transplanting. After the final land preparation EM solution in the ratio of 1:1:100 (EM: Molasses: Water) is sprayed. One month old seedlings after soaking roots in EM solution for more than 1 hour are transplanted in rows at a spacing of 30cm X 20cm. Transplanting took place in the 3rd week of July and harvesting in the 3rd week of October.

Rice yields over the years are presented Table 19. After the initial high yield there was a dip but now the yields are improving steadily, becoming comparable with the ones where chemical fertilisers are used. The effect of organic inputs and EM is becoming evident. Weed pressure is also declining. Last year the number of weeding carried out was three but it has reduced to two this year. So far there has been no pest and disease problems. It has been observed that there are more beneficial insects such as cricket and earthworms present in the soil. But despite of their beneficial behaviour, they are creating problem in retaining water in the terrace by boring holes in the bunds and walls.

Wheat

For the first two years the variety grown was Sonalika and after that BK-2 has been grown. After the first ploughing, 7t/ha of EM Bokashi is spread 4-7 days prior to sowing. During the final land preparation 5t/ha of FYM is applied. The seeds are soaked in EM solution for more than 2 hours. The seeds are broadcast in November-December and harvested in May. EM solution is sprayed after 30-45 days of sowing. Irrigation and other management practices are normal.

The yield data is shown in Table 19. The yield of wheat is comparable as well to the one where chemical fertilizer is used, and has been showing improvement over the years.

Mustard

For the first two years PT 30 was grown, thereafter M-27 has been grown. The land preparation and cultural practices are similar to those of wheat. The seeds after soaking in EM solution were broadcast in the 1st week of December and

harvested in the 1st week of April. The sowing was delayed as opposed to the ideal time of early October to November.

The yield result since 1995 is presented Table 19. The yield has been increasing as compared to those of last years. There was no pest and disease problems.

Maize

Maize is a dryland crop, but can well be grown in the wetland system. Land preparation and EM application is same as in wheat and mustard. Seven t/ha of EM bokashi and 5 t/ha FYM are applied prior to sowing. Seeds are sown in lines at a distance of 50-60 cm row to row and 40-50 cm plant to plant. Results are presented in Table 19.

Table 19 Grain yields (t/ha) of cereals in Nature Farm from 1995-99

	Y E A R			
Crop	95-96	96-97	97-98	98-99
Rice	8.70	4.40	5.05	6.26
Wheat	0.76	1.25	1.05	1.20
Mustard	0.26	0.27	0.41	0.48
Maize	6.37	5.82	6.84	7.70

Varieties used:

Rice	IR 64
Wheat	Sonalika, BK-2
Mustard	PT30, M-27
Maize	Yangtsipa

Fruit and other trees

Few fruit trees are also grown in and arround the Nature Farm. Among fruits, local varieties of pear from Tsirang, banana, mandarin, guava, and tree species such as *Melia azedarach, Ficus* sp., and *Bambusa* sp. are planted. EM bokashi and FYM were applied during the planting time. EM solution is also sprayed from time to time. Weeding/bush clearing is done twice a year. After weeding EM bokashi and FYM are applied. For disease and pest control EM5 is sprayed. However, no pest problems have occurred thus far.

Through work experience and observations, it is being realised that organic farming requires a number of years to manifest tangible results. It seems that organic farming could be economically viable although economic analysis is not done. The yields are comparable to those of inorganic farming. Till now there has been no pest and disease problems. It is still too early to draw any conclusions as these results are only preliminary and indicative.

2 HORTICULTURE

2.1 Subtropical Fruits

Introduction

The activities on fruits research concentrated on evaluation of the existing germplasm both on-station and on-farm. Equal efforts were also made in sourcing, introducing and establishing new germplasm both exotic and local to increase the number of collections for evaluation. From the various on-station varietal adaptability trials new results have been generated in citrus, mango, apricot and sub-tropical apple. On-farm evaluation of the promising cultivars have been further strengthened with the establishment of three demonstration orchards at three elevations in two dzongkhags. New results have been also generated in the field of propagation technology with the veneer grafting of mango, patch-budding of walnut and cleft grafting of avocado. Trials are also conducted to improve the management aspects of citrus orchards. A fertiliser trial to ascertain the right amount and right timing of application is underway. A trial is in progress to ascertain the right timing of irrigating citrus orchard. A trial is on-going to ascertain if poor management is the cause of the declining citrus orchard at the Phuntsho Pelri Palace orchard.

2.1.1 Integrated germplasm collection and development

2.1.1.1 Peach varietal evaluation

This trial is carried out with the objective of identifying promising peach cultivars, which are adaptable to low chill areas in the region. The parameters considered for selection are tree growth, fruit size, TSS % and yield. The treatment consists of three cultivars with five replicates each. The plants are planted in a spacing of 5m row to row and 4m in row. All management aspects are carried out during the season.

Table 20: Fruit characteristics and yield of three peach cultivars

Cultivar	Fruit color	Flavor	Yield/tree (kg)	TSS%	Remarks
Shane-I-Punjab	Red	Sweet	40	9-10	Suitable for low-chill area
Floridasun	Yellow	Sweet	35	10-11	”
July Elberta	-	-	0	-	High-chill var.

Harvesting was staggered over three periods of harvest, as the fruits matured at different times. Of the three cultivars Shan-I-Punjab yielded higher than the other low chill cultivar Foridasun, though they are harvested at the same time in mid May. In terms of fruit size Shan-I-Punjab is bigger than Floridasun though the latter is sweeter and has better flavour. Heavy pruning affected the fruit number , however, the fruit size has improved. Both Shan-I-Punjab and Floridasun performed well over three consecutive seasons and are promising cultivars with

the added advantage of coming into the market much earlier than other known cultivars so far. Both the varieties are already in the farmers' field for further evaluation. July Elberta was found to be a high chill variety which was evident from untimely flowering and flushing and poor fruit set.

2.1.1.2 Varietal evaluation of two apricot cultivars

Apricot is one stone fruit which has huge potential for commercial cultivation but it is still not cultivated at the same scale as other stone fruits like peach and plum. The objective of this trial therefore is to identify superior apricot cultivars which are suitable for low chill areas. The trial is set similar to the peach trial with two cultivars.

Table 21: Fruit characteristics and yield of two apricot cultivars

Cultivar	Yield/tree (kg)	TSS%	Remarks
New castle	12.83	17-18	Average of 2 plants
Kaisha	< 0.5	18-20	

The cultivars are suitable for low chill - warm temperate and dry sub-tropical, areas. The crop could be harvested in mid May, which is about 1 month ahead of any local or introduced varieties. The cultivar New castle has small fruit size compared to the cultivar Kasiha. The average yield of New Castle is much higher than the Kaisha. It could be because New castle is in its second year bearing while Kaisha is in its first year bearing. The TSS % for Kaisha is sligghtly higher than that of New Castle, though both the cultivars are extremely sweet cultivars. As it has high sugar content there is a potential risk of destruction by birds and wasps as evident from this trial. The variety shall be furhter tested in farmers field to test their preference and response to the two cultivars.

2.1.1.3 Varietal evaluation of different citrus cultivars

To diversify the production base of our citrus industry it is necessary to introduce and evaluate different types of citrus cultivars. This trial is a step in this direction, to expedite the process of diversification of citrus cultivation. Twelve cultivars of different citrus with 3 plants per cultivar were introduced through the auspices of the IHDP phase I in 1994, and planted in the evaluation orchard at a spacing of 4m in row and 5m between rows, with the objective to evaluate adaptability and performance of the cultivars. The performance parameters considered for selection are fruit quality – size, juiceness and taste. The trial is scheduled to be completed by the sixth year of planting, when the trees are expected to come into full bearing. Of the twelve cultivars eight have reached 3rd year bearing and results are presented below.

Table 22: Yield and other fruit traits of citrus cultivars

Variety	No. of fruits	size (G:H) cm	Shape	Harvest time	Fruit yield/tree(Kg)	Juiciness	Seeds	TSS
Ichifumi Wase	8	7.16:4.16	Flat	Mid Oct.	0.795	Juicy	Seedless	12-13%
Okitsu wase	35	6.63:4.43	Sightly round	Late Oct	5.9	Juicy	Seedless	8-9%
Matshu Ushui	9	6.3:8.26	Round	Mid Nov.	1.5	Juicy	Seeded	8%
Oota Ponkan	25	7.97:5.9	Semilar to local	Late Nov.	7.37	Very juicy	Seeded	10%
Encore	54	8.3:5.9	Flat	Early to mid Jan	3.36	Juicy	Highly seeded	10%
Seminole	47	8.26:6.73	Round	Late Jan	7.8	Highly juicy	Seeded	8%
Iyo	4	10:9.5	Round	Nov.	1.0	Highly Juicy	Seeded	8%
M.Iyo	14	8.26:7.5	Round	Nov	4.0	Highly juicy	Seeded	8%

Of the fifteen cultivars Ichifumi Wase (satsuma mandarin) matures 7-10 days earlier than the other satsuma cultivar Okitsu wase. It is most sweet amongst satsuma varieties. Okitsu wase on the other has firm fruits. Oota Ponkan (normal mandarin) is similar to our local mandarin but matures about a week early. Seminole has high acidity but is quite juicy. Miyuachi-Iyo and Iyo are both Tangor which bears large fruits and highly juicy. Miyauchi Iyo seems to be a regular bearer. Encore (hybrid mandarin) is a late maturing cultivar with good fruit quality. Based on the trial results Ichifumi, Okitsu and Oota Ponkan.

All the lime and lemon cultivars have good fruit qualiies and are superior to the existing local lime lemon. Although fruit yield data are not presented in the table as most of the varieties are at juvinile phase. Few plants started to bear fruits in the nursery of which cultivars like Freemont, Clementine, Valencia, Bearss, Meyer, Minneola, Miyagawa wase are found promising.

Ichifumi Wase, Oota Ponkan, Fremeont, Clementine are being tested in the farmers' field at different agro-ecological zones for further tests of preference, adaptibiltiy and acceptability.

2.1.1.4 Mango evaluation

Mango cultivation has been so far limited to the hotter and wetter regions like the foothills. There is however evidence that it could be grown at places like the Punakha-Wangdue valleys. To reach a conclusive finding in this the mango trial to determine the adaptability and performance of mango in this area has been undertaken. Five cultivars have been established in the trial and results have started to emerge. The trial consists of the five cultivars replicated three times, planted at spacing of 8m between rows and 7m in row. Normal cultural practices have been administerd seasonally. The parameters considered for selection have been tree growth, fruit quality and fruit yield.

Table 23: Fruit yield and other characteristics of Mango varieties

Variety	Fruit size dia (cm)	Fruit length (cm)	Yield/ tree (kg)	TSS (%)
LANGRA	9.33	11.33	1.62	16-17
Himsagar	8.33	10.26	7.99	16-17
Dushari	6.33	10.40	0.86	17-18
Amrapali	8.26	11.90	1.73	18-19

All the cultivars have established well in the field and started bearing reasonably well too. Of the five cultivars Himsagar matures about a week earlier than other varieties. It has a medium fruit size and good flavour with good scent. Amrapali on the other hand is the sweetest variety and is a late cultivar. Dasheri and Langra are mid season with also good fruit quality. From the trial result it could be deduced that all these cutivars are adaptable to this condition and are suitable for cultivation. However there is a need to further evaluate their perfomance under different micro-climatic conditions through on-farm testing.

2.1.1.5 Pear evaluation

Pear is one potential crop for sub-tropical conditions though its cultivation is limited to few pockets. Also there is a need to evaluate different cultivars suitable for different ae conditions. The objective of this trial is therefore to identify cultivars which are suitable for low chill areas like the sub-tropical regions. Four cultivars of pears have been established at a spacing of 4m in row and 5m between rows. The parameters to determine the adapability and performance have been tree growth and fruit quality.

Table 24: Pear fruit yield and other fruit traits

Variety	Fruit shape	Fruit size		Juiciness	Fruit wt/tree (kg)	TSS (%)
F. beauty	bell shape	5.33	6.37	very juicy	1.40	14
China	oblong	5.16	4.70	juicy	1.00	14
Gala	round	6.70	5.56	Juicy, bitter	4.75	13
Tsirang local	oblong	7.33	5.76	juicy, bitter	3.50	10

All the cultivars seem to be adaptable to this condition looking at the tree growth and bearing quality of the trees. Tsirang local matures early but it has bitter taste. Flemesh Beauty and China are most promising in term of fruit quality.
Furhter on-farm testing is required to determine the real adapabilty and performance of these cultivars.

2.1.1.6 Germplasm introduction during the year

During the current year the following new introduction and indigenous germplasm collections were made. For total inventory of germplasm so far refer Appendix 4.

Variety	**Source**
Grapes Muscat of Alexandria	HOLLAND, IHDP-II
Early Steuben	DSC, Paro, RNRRC
Portland Green	DSC, Paro, RNRRC
Campbell's early	DSC,Paro, RNRRC
Calmeria	FRANCE, JG.AG
Ruby seedless	‘’
Sultana	‘’
Waltham Cross	‘’
Avocado	
Zutano	California, IHDP-II
Pinkerton	‘’
Hass	‘’
Fuertte	‘’
Bacon	‘’
Local	Zhemgang, RNRRC
Pecan rootstocks	
Greenriver	France, JG.AG
Hodge	‘’
Peruque	‘’
Giles	‘’
Sub-tropical apple	
Einchimier	Egypt, JG.AG
Pear	
Egyptian	Egypt, JG.AG
Hosui	DSC, Paro, RNRRC

Kosui ‘’
Walnut
1500 seedlings from Mongar
325 seedlings raised at Bajo
Cardamom
Ramsey clonal selection

2.1.1.7 On-farm

Two sites for demonstration and evaluation of sub-tropical fruit trees under farmers’ management level was selected and fencing with MS angles has been completed. At one site six citrus varieties and one Pomegranate variety has been planted. Backyard fruit cultivation has been established in the watershed for peach, pomegranate and some citrus cultivars which have proven promising in on-station trials. Cardamom Seedlings grown from clonal selection has been established at Darachu under Tsirang dzongkhag. Precaution against Wilt has been taken by application of Dolomite and lime. Local mandarin trees for regular bearing habit is being monitored at Tsirang. The difference in performance and other fruit traits will be reported in next annual report.

2.2 Vegetables

2.2.1 Potato Preliminary variety trial for the rice based system

The main objective of the trial was to evaluate the performance of the new varieties for yield, maturity and disease resistance in the rice based system.

Varieties 378015.13, 381379.9, IP87002, 377957.5, 378699.22, 800934 and Desiree were planted in plots sized: 2.4 m X 3 m with a spacing of RR 0.6m, PP 0.25m. Fertilisers at the rate of 100:80:30 NPK kg/ha (half N and all P,K at planting and the remaining N top dressed at 40-45 DAP). The trial was conducted using the randomised complete block design with 3 replications.

The main measurements taken were emergence 30 and 50 DAP, number of stem after full emergence but before plants touch between rows, no and yield of large, small and seed size tubers from the two center rows, and pests and diseases. The earliest variety (378015.13) was ready for harvest by the 29th of May 1999, while the local check was ready after two weeks. All the others were ready for harvest only 133 DAP.

The highest total yield was observed in the local check Desiree with an average of 20.62 t/ha, followed by 378015.13 with 19.03 t/ha. 381379.9 also yielded high with an average yield of 18.11 t/ha. There were no significant differences in total yield amongst the above varieties. Desiree also produced the highest large sized tubers at 13.26 t/ha, followed by 381379.9 at 11.18 t/ha. The other varieties produced tubers ranging from 5-9 t/ha of large sized tubers. 378015.13 produced the highest seed sized tubers at 11.06 t/ha. The others all produced fairly low seed sized tubers ranging from 2-5 t/ha. 800934 produced the highest small sized tubers, followed by IP87002. There were no significant differences in the number of stems per plant except for 378699.2, which had an average of 7.75 stems per plant.

Table 25 Yield and other characteristics of 8 potato varieties

Variety	total yield (t/ha)	large sized (t/ha)	seed sized	small sized	no. of stem/ plant	emergence 40 DAP	emergence 50 DAP	days to maturity
378015.13	19.03	6.39	11.06	1.58	2.83	40	46	112
381379.9	18.11	11.18	3.8	3.13	3.46	23.3	42	133
IP87002	17.43	9.01	4.12	4.31	4.51	24.7	42.33	133
377957.5	14.24	6.89	4.35	2.99	4.65	21.7	35.67	133
378699.2	13.03	9.86	2.22	0.95	7.75	16.7	29.33	133
800934	15.3	5.51	4.4	5.39	3.08	36.3	41.67	133
Desiree	20.62	13.26	5.93	1.43	5.05	21.3	41.33	123
Cv%	12.8	24.1	22.1	65.8	50.8	25.4	10.5	0
$LSD_{0.05}$	3.834	3.8	2.01	3.3	4.04	11.87	7.42	0

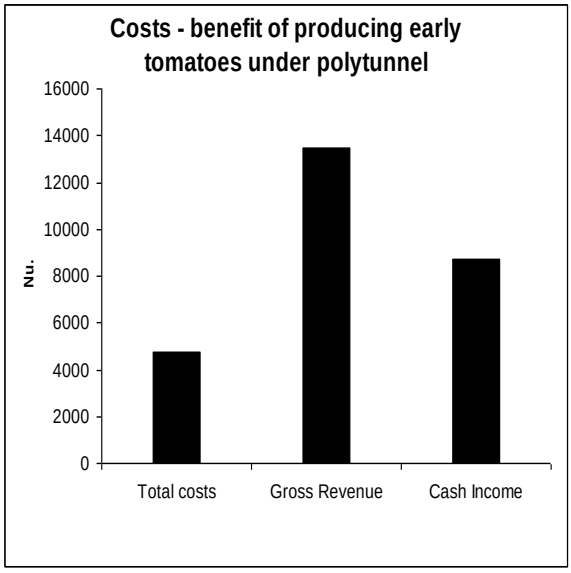
2.2.2 Early tomato cost benefit analysis

A trail was conducted in the last season to determine the best suitable variety of tomato for off-season production under polyethylene tunnel. Amongst five varieties, RATAN from Bangladesh performed the best. Harvest by March was possible, when no tomatoes are available in the market. The main objective of the trial was to determine a detailed cost-benefit analysis of early tomato production under polytunnel.

The polytunnel used was the standard AMC structure. Detailed records of every activity, inputs, labour etc were kept till the trial was terminated. The seeds were sown in the nursery in the third week of November and transplanted after one month in the polytunnel. ie. 3rd week of December. The size of the standard polytunnel was 20m x 5m. Transplanting was done at a spacing of 65 cm RR and 25 cm PP. All necessary cultural practices were carried out and recorded. Harvest was possible by the end of March. A total of 10 pickings were done.

The total marketable yield was 448.36 kg. At a price of Nu.30 per kg , the Gross Revenue earned was Nu. 13450.8. The expenditure was broken down in several components. Expenditure on materials/ inputs added up to Nu. 1378.90, labour cost at Nu 10 per hour, 159 hours added up to Nu. 1590. The inventory list was drawn on all tools, equipment and other infrastructure used. Depreciation calculated with the life span and price of the material was made and thus the cost of the material for the particular year was determined. The inventory cost was Nu.1779.24. The total costs added up to Nu 4748.15. With gross revenue of 13450.8, the cash income generated in one year is Nu.8702.65. (see Appendix 5 for detailed list)

Figure 1 Total costs, gross revenue and cash income of early tomatoes under polytunnel



2.2.3 Vegetable dryer

With the objective of minimising post harvest loss and properly utilising excess vegetables, a small scale, low cost electric vegetable dryer was built, tested, and displayed in the centre. Other objectives were:

- to develop a technology appropriate to farm level use and production, with value added potential
- to extend the technology across the country for further testing and exposure to the public
- to supply to and encourage existing interest in the technology
- to encourage entrepreneurial persons to diversify horticultural commodities in the market

The test results have been promising, producing good quality dried vegetables at low cost. Traditionally consumed vegetables as well as those with market potential have been tested. Food materials other than vegetables, like meat, cheese, fruits were also dried. The initial design has proved to be functional and reliable to date (one year operation), with minor modifications made during the course of testing. Farmers and small business people, having seen the dryer, have expressed interest in the machine.

With the support of IHDP, more dryers were built, all based on electricity, for wider trial. Some designs were modified to reduce cost, increase reliability, and simplify electrical components. Some preliminary test results are produced in the sheet (Appendix 6). The total costs of drying the materials were also calculated.

Figure 2 Vegetable dryer

2.2.3 Off-season cauliflower production

One of the important objectives of vegetable research is to increase local off-season vegetable production to replace imports. This objective can be realised through the evaluation of suitable crops and varieties. Cauliflower being a thermosensitive crop, varieties differs in temperature requirement for curd initiation and development. Selection of suitable variety for a particular season is important. Since the seeds of only Pusa Deepali were available, the other varieties were not included. Snowball 16 was planted as the local check. The main objective was to extend the availability of cauliflower by early December.

The trial was set as an observation trial. There were not enough materials for replication. The plot size was 1m x 6m with a spacing of 60 cm RR and 50 cm PP. The seeds were sown in the nursery on the 29th of August and transplanted on the 26th of September 1998. Irrigation was done as and when required using sprinklers. Recommended fertilisation and other cultural practices were followed.

The curds were ready for harvest by late November till the end of December. Pusa Deepali matured earlier than our local check by 30 days. The horticultural characteristics and yield are given in the table below.

Table 26 Yield and other traits of cauliflower varieties (off season production)

Characteristics	Varieties	
	Pusa Deepali	Snowball 16
Days to maturity	93	123
Yield/ha (t)	15.5	14
Curd colour	White	Off white/yellowish
Curd length (cm)	9.67	10
Curd width (cm)	14.6	15.6
Plant height (cm)	35.6	65
Plant width (cm)	48	58.1
Disease & Pests	None	None

2.2.4 Cabbage off-season trial

Commercial cultivation of cabbage for head production is not a problem in Wangdue. The climatic conditions are not favourable for seed production of cabbage, which is greatly influenced by low temperature, a critical factor to induce flowering. BARI, Bangladesh has identified a variety named Provati, which has the potential to set seeds in the warm winter conditions of Bangladesh. This study was undertaken to observe the seed producing ability of the variety under our climatic condition in Wangdue. It also observed the head characteristics of the variety in comparison to the two popular local check varieties.

The variety from Bangladesh, Provati was tested along with the two local checks, Golden Acre and Copenhagen Market. The seeds were sown in the nursery at the end of September 1998 and transplanted in the field after one month in plots sized

10 sqm. The spacing was 60 cm RR and 50 cm PP. The trial was laid out in a randomised complete block design with three replications. All recommended cultural practices were carried out accordingly.

Table 27 Yield and characteristics of cabbage varieties

Variety	Plot yield (kg)	Nos/plot	Plant ht (cm)	Plant wt (cm)	Head ht (cm)	Head wt (cm)
Copenhagen Market	26.5	30.33	19.3	37	13.5	14.33
Golden Acre	23.3	31.33	22.3	37	12.33	13.33
Provati	11.4	18.33	21.0	36.33	14.33	14.33
cv%	18.3	5.3	15.7	8.0	10.0	7.7
$LSD_{0.05}$	8.46	3.206	7.44	6.652	3.023	2.445

The two local varieties significantly out yielded Provati, the test variety. There were no significant differences in the head and plant sizes. The Black rot disease affected a few plants of Copenhagen Market. Golden Acre was free of any pest or disease problem. There was some problem with the test variety Provati. Some plants were fully bolted and those that were intact showed signs of bolting when dissected. This has probably got to do with the 'tropical' characteristic of the variety, which has been specially bred, for producing heads in high temperature. A detailed temperature record during the growing season will have to be studied to understand the problem. The variety will also be tested for production during summer.

2.2.5 Potato onfarm trial (mid altitude)

The main objective of the trial was to evaluate the performance of two promising varieties in comparison to the local check for yield, earliness and resistance to disease and pests. The lines 720060 (white) and 378699.22 (red) were sown in the farmer's field on 2.4.99. The trial was laid out in a RCBD with three replications. Plot size was 2.4m x 3m, with four rows and 12 tubers per row. Harvest was done from the two middle rows. Tubers of different sizes were categorised as small, seed size and large tubers. The numbers of tubers and weight were recorded.

Gaselo (Hebesa)

Table 28 Yield of potato varieties tested at Lower Gaselo

Variety	Total yield (t/ha)	Remarks
378699.22	14.68	matures in about 108 days after planting
720060	9.94	matures in about 108 days after planting farmers prefer its taste although the skin colour is white
Local	19.63	matures in about 90 days
$LSD_{0.05}$	14.179	
cv%	42.4	

The local variety was ready for harvest in about 90 days after planting. It yielded higher than both the test varieties in all types of tubers, producing a total yield of 19.6 t/ha. Although there were no statistically significant differences in the yield of the three varieties, variety no. 720060 produced the lowest yield of 9.94 t/ha followed by 378699.22 with 14.68 t/ha. There were no major pests and diseases observed during the course of the trial. A small incidence of cutworm (Agrotis spp) was observed initially but a spray of Cypermetherin at the rate of 0.5 ml/Lt brought it under control. Farmers found the variety 378699.22 being slightly resistant to the cutworm attack. However, the cooperative farmer liked the taste of the variety 720060.

Limbukha

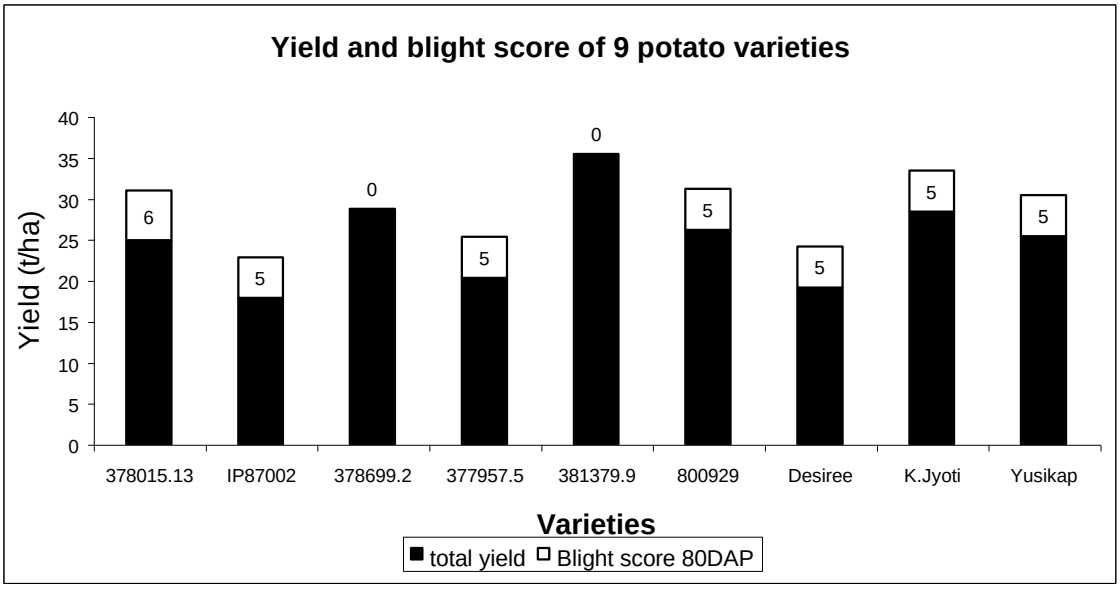
The local variety produced the highest yield of 11.94 t/ha. The two test varieties took longer to mature and produced small tubers. However, the co-operative farmer will try growing one of the test varieties i.e. 378699.22 next year by sowing earlier.

Table 29 Yield of potato varieties tested at Limbukha

Variety	**Total yield (t/ha)**	**Remarks**
378699.22	7.417	took longer time to mature. farmer prefers its colour i.e red skin
720060	4.611	took longer time to mature white skin.
Local	11.944	matured early
lsd (0.05)	6.17	
CV%	34	

2.2.6 Potato trial (High altitude)

The main objective of the trial was to evaluate five promising potato varieties for yield and disease resistance in high altitude areas where potato is the main crop. A blight hot-spot site (Khotokha) was chosen as the trial site. The trial was laid out in RCBD with three replications. Each farmer served as one replication. The plot size was 2.4m x 3m, with four rows and 12 tubers per row. The field was pre irrigated prior to sowing. Sowing was done on the 31st March 1999. Farmyard manure was applied, but no chemical fertiliser was applied. No other PP chemicals were applied. Weeding, hoeing and earthing up was done only once. Harvesting was done on the 4th August 1999.



Note: Blight Score: 0= no symptoms, 9=all plants dead.

Figure 3 Yield and blight score of 9 potato varieties tested at Khotokha

This trial being a late blight resistance screening trial, blight scoring was done 70 and 80 days after planting. It was observed that most of the varieties tested showed similar symptoms in reaction to the disease with the exception of varieties 381379.9 and 378699.2, which were not affected at all. These varieties also yielded the highest total yields of 35.37 t/ha in 381379.9, followed by 28.7 t/ha in 378699.2. Kufri Jyoti, one of the local check varieties produced a high yield of 28.38 t/ha inspite of showing a slight incidence of the disease.

A general observation in the growing season was that there was no major incidence of late blight in most of the potato growing regions. However, the above varieties may be further tested.

Table 30 Performance of 8 potato varieties tested at Khotokha

Variety	Total yield	Yield (t/ha) large sized	seed sized	small sized	emergence 50 DAP	Blight score 70 DAP	Blight score 80 DAP
378015.13	24.91	14.26	7.82	2.82	43.00	5	6
IP87002	17.82	10.79	5.19	1.85	34.33	2	5
378699.2	28.70	18.24	8.98	1.48	37.33	0	0
377957.5	20.27	12.44	6.44	1.39	42.67	4	5
381379.9	35.37	24.17	9.44	1.76	44.33	0	0
800929	26.16	11.20	10.51	4.44	41.00	2	5
Desiree	19.12	11.48	6.48	1.16	39.00	2	5
K.Jyoti	28.38	20.37	7.22	0.79	42.67	3	5
Yusikap	25.37	10.42	12.64	2.31	44.33	4	5
Cv%	17.1	24.4	18.7	44.3	5.6	12.5	12.2
$LSD_{0.05}$	7.43	6.255	2.684	1.535	3.964	3.964	0.881

2.2.7 Onion onfarm trial

Four potential varieties form India were tested in 4 farmer's fields for yield and bulb characteristics and for attaining farmers' preferences. The variety AFDR was observed as the check variety being already popular among onion growers in the valley.

Sowing was done by the end of September to early October. The seedlings were transplanted after seven or eight weeks. The total plot size was 20 m2 per variety and the harvest plot was 10 m2. Harvesting was done in the month of May. Fresh bulb weights were taken and recorded as yield. The bulb size was taken form 10 bulbs randomly selected per variety. Some aspects of farmer preference were recorded by asking the co-operating farmers.

Table 31 Yield of four onion varieties in different farmers fields

Variety	Total yield (t/ha) Locations				
	Bajo	Gubjee	Damche	Guma	Average yield (t/ha)
Arka Kalyan	12	16.42	12.76	22.40	15.9
Arka Niketan	11	15.71	15.41	15.35	14.4
AFDR	12	10.71	13.32	14.28	12.6
Red Creole	11.5	24.28	11.66	28.57	19.0

(Cv% 26.1, lsd (0.05) 6.46)

Table 32 Bulb characteristics of four onion varieties tested in farmer's field

Variety	Bulb size			
	Bulb dia (cm)	Bulb length (cm)	Bulb weight (gm)	Colour
Arka Kalyan	5.8	3.7	91.0	red
Arka Niketan	5.3	4.6	90.3	red
AFDR	5.1	4.0	70.3	red
Red Creole	5.2	3.1	115.0	dark red

There were no statistically significant differences in the yielding ability of the four varieties. Red Creole produced the highest yield of 19 t/ha followed by Arka Kalyan and A. Niketan at 15.9 and 14.4 t/ha respectively. AFDR yielded the lowest with 12.6 t/ha. Farmers also did not prefer the variety AFDR, which they remarked of being small sized and bolting. Farmers preferred both the varieties Arka Kalyan and Arka Niketan, being higher yielding, producing medium sized bulbs but the most preferred variety was Arka Niketan, which did not bolt at all. No storage tests were done.

2.2.8 Tomato onfarm trial

Two promising tomato varieties Ratan and Pusa Sheetal were tested in three farmer's field. Roma was used as the local check.

Gaselo (Hebesa)

Transplanting was done on 16th April 1999. The trial was laid out in a RCBD with three replications. The plot size was 10 m2 and the harvest plot was 5m2. The plants were spaced at 60 cm row to row and 60 cm plant to plant. The first harvest was done on 21st June and carried on till the end of July, a total of 3 harvests were done.

Table 33 Yield of tomato varieties

Variety	Mean yield (t/ha)
Pusa Sheetal	20.13
Ratan	23.40
Roma	15.21
cv%	5.5
$LSD_{0.05}$	4.225

There were no significant differences in the two new varieties. Of the two, Ratan produced a lightly higher yield. Both yielded significantly higher than the local check Roma. Farmer prefers Ratan to the other two, his criteria for preference being good taste, uniform shape and acceptability to consumers. Ratan sold out faster than the other two in a market place. There were no disease problems. A slight problem of fruit borer was observed but a spray of Cypermetherin at the rate of 0.5 ml/1lt water was applied on the first visible attack.

Limbukha

The two varieties were also planted in six farmer's field in Limbukha. The farmers there experienced some problem with management, providing staking and a slight incidence of wilt. Although no data were recorded, farmer's reaction was sought through casual interviews. The farmers preferred the variety Ratan, owing to its characters like uniform size, colour and shape. Consumers selected Ratan out of a mixture when sold in a local market.

2.2.9 Asparagus onfarm trial

Seeds of variety Franklim were supplied through the IHDP. The nursery was raised in the center in 1998. In 1999, about 6000 asparagus crowns were distributed to farmers in Punakha, Gasa and Wangduephodrang Dzongkhags. Basic cultivation techniques were imparted at the time of transplanting, both to the farmers and the extension.

2.2.10 Seed production and maintenance

Table 34 Vegetable seed produced 1998-1999

Crop	Varieties	Remarks
Tomato	Pusa Sheetal	India. Selected from 1996 experiment being slightly cold tolerant and resistant to blight disease
Tomato	Ratan	Bangladesh. Selected being better than Roma in yield longer shelf life and suitable for off season production inside poly- tunnel
Bottle Gourd	Midnapur Round	India. Selected due to high yielding and good taste. Needs further testing with local farmers
Yard long bean	TVRC	Thailand. Long and high yielding. Provides variety
Onion	Red Creole	Italy Rome. long shelf life though yield is not very high
Saag	Marpha broad leaf	Nepal. Good leafy characteristics. For further testing
Cherry tomato	160	AVRDC Line. Good for continuous bearing in kitchen gardens. Tasty but indeterminate type

2.2.11 Other Activities

Aparagus evaluation

The nine hybrid asparagus varieties planted in 1996 continue to be evaluated for yield and other aspects.

Exotic vegetables and herb tests

New vegetables and temperate herbs have the potential of servicing the increasing numbers of tourists in Thimphu and changing tastes of people shopping at the Thimphu market. Production tests were carried out to indicate the potential for promoting these varieties for commercial production. Various new vegetables like Kohlrabi, Savoy cabbage, Kale, Lettuces, Zucchini and herbs like Sage, marjoram, basil, parsley, dill etc were grown for observation.

All the vegetables grew quite well. Local staff enjoyed some of the vegetables but did not actually know how the herbs were used. Another part of the trials was to conduct the market preferences and views from potential consumers. However, this could not be carried out last season. A set of Mexican chillies was also grown for observation. Of the 7 different types (Pasilla, De Arbol, Serrano, Anaheim, Mulato, Jalapeno and Habanero) Habanero, the world's hottest chilli was also grown successfully.

EA & Farmers training

- A special vegetable training for the extension agents of Punakha Dzongkhag was conducted in March 1999.
- Hands on vegetable production for the extension and some farmers of Gasa and Laya were conducted in May 1999.

National RNR Exhibition

The preparations for the National RNR Exhibition began early in January in the form of growing a GIANT PUMPKIN. The seeds of Atlantic Giant were sown in poly pots in early January and kept under polytunnel house. The seedlings were transplanted also under the polytunnel house. Daily care and maintenance to the four plants were given. After the pumpkins reached basketball size, only two fruits were retained per plant. The fruits grew at a rate of 5 cm per day. The largest fruit weighed 85 kgs. Although four fruits produced good size, some got rotten due to heavy rain. However, it was a big eye catcher during the June 2 Exhibition.

3 LIVESTOCK

3.1 Feed and fodder research

3.1.1 Introduction nursery - subtropical species

The trial was established with the objective to introduce and evaluate subtropical legume and grass species and as a demonstration plot for training purposes. A total of 43 legume and 18 grass entries were established on-station on 29th May 98 and 9th June 1998 respectively in single plots 3 rows 30 cm apart, 3 m long and 1.5 m border between each plot. Application of 50 kg P_2O_5 per ha before seeding for all plots and 30 Kg N per ha for grass species 40 days after sowing and after each harvest was done. The methodology planned was to count plants germinated in 6 randomly selected segments of 50 cm row at 20 days after planting and bio-mass rating 50 days after planting which was carried out as planned but the seed production and dry matter yield which was supposed to be done towards the end of growing period around beginning of November was changed due to weed competing the plots. The plots were harvested whenever it was required. The best performer among legume species was *Desmodium rensonii* with biomass of 60.3 t/ha (Table 35) followed *Macroptilium atropurpureum* at 48.3 t/ha and among grass *Paspalum atratum* 55.1 followed by Chloris gayana at 52 t/ha. The grass species will be evaluated further but had to discontinue legumes since most of the species didn't survive.

Table 35 A list of tested legume entries and their performance

Species	ILCA/CIAT	Total plts.	Biomass 50 days after	Biomass 7/9/99	Biomas2/ 11/99	Biomass 11/6/99	Total 3 cuts
Stylosanthes guianensis	73	120	1.8	20.0	13.5	9.0	42.5
	164	90	2.5	21.0	9.0	0.0	30
	163	65	2.4	19.0	9.0	0.0	28
	Cook	40	1.1	10.0	9.0	0.0	19
	184	50	2.2	30.0	15.8	0.0	45.8
	FM05-3	79	1.4	28.0	9.0	0.0	37
	FM05-1	68	0.7	15.0	4.5	0.0	19.5
S. hamata	75	70	0.9	16.0	11.3	0.0	27.3
	167	55	1.2	9.0	0.04	0.0	9.04
S. scabra	140	68	0.3	2.0	0.45	0.0	2.45
	11625	10	0.1	1.0	0.9	0.0	1.9
	12555	8	0.5	0.5	0.0	0.0	0.5
	441	30	0.0	3.0	3.4	0.0	6.4
S. viscosa	6860	5	0.7	0.0	0.0	0.0	00
Chamaecrista rotundifolia	9288	48	1.4	1.0	2.3	0.0	3.3
	10915	42	2.9	3.0	0.0	0.0	3.0
	14165	50	1.8	10.0	7.9	0.0	17.9
	14168	35	2.2	5.0	6.8	0.0	11.8
	Wynn	45	2.5	25.0	7.9	0.0	32.9
Zornia latifolia	172	0	0.0	0.0	0.0	0.0	00
Pueraria phaseoloides	156	50	2.2	15.0	9.0	9.9	33.9
Macroptilium atropurpureum	69	62	5.5	12.0	25.0	11.3	48.3

	397	49	3.7	12.0	18.0	11.7	41.7
Macroptyloma axillare	6756	44	3.3	13.0	0.0	4.5	17.5
	6959	71	0.7	3.0	18.0	4.5	25.5
Neonotina wightii	6761	56	3.3	9.0	0.45	9.5	18.9
	9794	63	3.4	8.0	15.8	9.0	32.8
	7764	69	3.7	7.0	14.6	9.0	30.6
	9979	58	4.0	10.0	13.5	9.9	33.4
Desmodium uncinatum	6765	39	2.2	6.0	6.8	9.5	22.3
Greenleaf desmodium		40	1.1	5.0	5.6	9.0	19.6
Desmodium intortum	104	20	1.4	10.0	4.5	4.5	19.0
Centrosema arenarium	12451	25	0.7	0.9	4.5	4.5	9.9
Centrosema pubescens	219	28	0.9	0.1	9.9	9.0	16.1
	15160	27	0.9	0.2	1.2	6.8	8.2
Centrosema brasilianum	155	35	0.7	0.2	9.0	0.0	9.2
Centrosema pascuorum	9857	37	1.8	16.0	22.5	0.0	38.5
Desmantus virgatus	312	16	1.1	10.0	6.8	0.0	16.8
	Bayamo	4	1.1	5.0	6.8	0.0	11.8
Arachis pintoi		1	0.1	0.1	0.0	0.0	0.1
Desmodium rensonii		79	11.1	40.0	13.5	6.8	60.3
Teramnus uncinatum	CIAT 9012	67	5.5	10.0	8.6	4.5	23.1
Medicago sativa	Stemina	60	4.4	3.0	6.8	11.3	21.1

Table 36 A list of grass entries tested and their performance

Species	ILCA/CIAT	Total plts.	Biomass 50 days	Biomass 4/9/98	Biomass 30/10/98	Biomass 11/6/98	Total 3 cuts
Brachiaria brizantha	CIAT 6780	0	0.0	2.0	0.0	9.6	11.6
Brachiaria brizantha	CIAT 6780	12	0.3	5.0	9.0	9.0	23.0
Brachiaria decumbens	Basilish	28	1.8	4.0		13.5	17.5
Brachiaria humidicola		0	0.0			9.0	9.0
Cenchrus ciliaris (nos 45)	Biloela	18	1.1	6.0	13.5	0.0	19.5
Cenchurus ciliaris	6653	0	0.0	0.0	0.0	5.4	5.4
Chloris gayana	Callide	35	1.1	7.0	36.0	9.0	52.0
	6633	55	1.4	4.0	36.0	0.0	40.0
	7384	O	0.0	0.0	0.0	18.0	18.0

Paspalum atratum	BRA 9610	42	2.5	8.0	31.5	15.6	55.1
Paspalum guenoraum	CPI 39962	8	0.3	1.0	18	0.9	19.9
Panicum maximum	6946	0	0.0	0.0	9	9.0	18.0
	Makeuni	5	0.3	1.0	31.5	0.0	32.5
	6299	0	0.0	0.0	0.0	9.0	9.0
Setaria sphacelata	Nandi	26	1.1	6.0	27	0.0	33.0
Urochloa moscbicensis (nos 47)	7104	0	0.0	0.0	0.0	0.0	0.0
Panicum coloratum	7153	0	0.0	0.0	0.0	0.0	0.0
Andropogon gayanus	CIAT 621	0	0.0	0.0	0.0	4.5	4.5

Table 37 Leguminous tree species tested and their performance

Species	Variety (ILCA no etc.)	Plt.ht.(m)8/10/98	Plt.ht (m) 7/12/98	Number of seedling survived 10/6/99
Leucaena leucocephala	70	0.44	0.79	12
	K636	0.44	0.77	12
Leucaena diversifolia	Ex philippines	0.48	0.77	12
	Ex Nepal	0.58	0.97	12
Leucaena pallida	14189	0.72	0.84	12
	14203	0.78	0.89	10
Calliandra callothyrsus		0.53	0.92	0
Sesbania sesban	10865	2.53	4.27	11
	1238	2.1	3.5	9
	1261	2.09	3.37	6
	1265	1.83	3.77	9
	1284	1.7	2.68	8
	1290	1.56	2.36	5
	15019	1.64	2.85	11
	15021	2.28	3.67	9
	15036	1.79	3.56	11
Acacia villosa		0.55	0.81	1
Crotalaria anagyroides		1.47	2.0	12
Flemingia macrophylla		0.56	0.92	12
Gliricidia sepium	Retalhuleu	0.62	0.86	0

3.1.2 Relay sowing in rice

The objective of the trial was to evaluate establishment technique, effect of planting date, develop rice-fodder systems to enhance soil fertility and increase winter fodder production. Three methods were tried i.e broadcast seeding 40 days before rice harvest (establishment date : 24/9/98), 20 days before rice harvest, and line sowing immediately after rice harvest (established on 1/12/98) A row to row distance of 25 cm was maintained. The trial was established in an RCBD with 3 replicates and 7 treatments (see Table 38 for details) in a plot size of 4m x 2m. The first and second method failed in all the species. Astragalus germinated well but disappeared due to heavy frost, very few hairy vetch germinated and the rest did not germinate at all. The same species did well in the third method. Two cuts were possible from Oat. First cut of Oat was done on 16/3/99 and second on 31/3/99 along with all other species. Oat was the best performer with a total biomass of 25.4 t/ha followed by hairy vetch with 22.5 t/ha.

Table 38 Plant ht and biomass of tested grass/legume species

Species	Seed rate (kg/ha)	Plant ht. (m)	Fresh biomass (t/ha)
Berseem	25	0.25	2.9
Crimson clover	25	0.11	1.4
Hairy vetch	80	0.38	22.5
Astragalus	15	0.31	4.1
Italian rye grass	20	0.30	5.2
Oat	150	0.60, 0.33	22.5, 2.9
Rye	150	0.45	6.7

3.1.3 Seed Production and Maintenance

Produced 100 kg oat, 15 kg Rye, 10 kg Sudan grass and 5 kg Hairy vetch seeds and slips of Napier grass which were readily available for further transplanting.

4 FORESTRY

Introduction

Forestry research program started at the centre from 1995. The research program focuses mainly on the social forestry sub-program and research activities have mainly been carried out in the fields of agroforestry and community forestry. The activities of the research program can be divided into three viz. at the centre, in the watershed and in the territorial Forest Management Unit.

4.1 Activities at the centre

The research program maintains a nursery at the centre where multipurpose tree species (MPTS) are raised and planted around the centre for further monitoring and also for landscaping.

4.1.1 Introduction and evaluation of MPTS

The objective is to evaluate and identify suitable species for social forestry activities besides expanding the diversity of species in use. Short-listed species among the native and exotic tree species sown between June 1997 and June 1998 at the centre's nursery were planted at the watershed. Local tree species were collected and sown in 1998-99. The list of species introduced are given in Table 39.

Table 39 List of species introduced during 1998-99.

No.	Native species	No.	Native species	No.	Exotic species
1	Eriolobus indica	10	Trema orientalis	19	Acacia villosa
2	Albizzia spp.	11	Albizzia lebbeck	20	Flemingia
3	Melia azedarech	12	Ficus bengalensis	21	Calliandra
4	Spondis axillaris	13	Ficus religiosa	22	Tithonia diversifolia
5	Alnus nepalensis	14	Chickrassis tubularis	23	Desmodium ransoni
6	Quercus lanata	15	Morus alba	24	Robina psedoacacia
7	Ficus roxburghii	16	Acrocarpus raxinifolius	25	Acacia arabica
8	Ficus cunia	17	Michelia champaca	26	Tamarindus indica
9	Cupressus	18	Albizzia procera	27	Cederla toona

4.1.2 Monitoring MPTS planted at the centre

The tree species are raised in the nursery during the course of evaluation are planted in the centre's wasteland every year for further screening and monitored regularly. The list of species planted around the centre are given in Table 40.

Table 40: List of tree species planted around the centre.

No	Tree species	NO. OF TREES	VISUAL ASSESSMENT
1.	Melia azedarach	200	height increment of 5mm; dbh increase of 35MM
2.	Bombax ceiba	19	Growth fair; branchy form.
3.	Cupressus	250	Straight bole formation, height growth good.
4.	Poplar spp.	50	Annual ht. increment 5m; 35mm dbh maintained.
5.	Salix babylonica	40	Good height and diameter increment.
6.	Ficus religiosa	08	
7.	Callistemom sp.	150	Total height of about 3m; profuse flowering.
8.	Dodonea viscosa	45	
9.	Thuja sp.	33	

4.2 Activities in the Lingmutey Chu Watershed

RNRRC Bajo has embarked on the Natural Resources Management (NRM) research in the Lingmutey Chu watershed in 1995. The objective is to adopt a farmer participatory research and identify appropriate methodology which integrates the RNR sectors for the management of natural resources. Social forestry and agroforestry were identified as one of the major components of the NRM research in the watershed.

4.2.1 Creation of community forestry nursery (CFN) in the watershed

A CFN was created (at Omtekha) to identify and generate diverse tree species suitable for fodder, fuel, timber, community plantation, gully plugging, hedgerow planting, and reforestation in heavily degraded areas. This also has a further aim of making implementation participatory and accessible to beneficiary communities and expose communities to nursery establishment and handling techniques. This is hoped will enable smooth transfer of nursery management technology to the community. Species raised include both native and exotic and are chosen by the community and based on the experiences of the participating institutions.

The seedlings generated from the nursery were planted on-farm/site for evaluation with regards various purposes and the appropriately identified species are to be promoted. The list of species available in the nursery are given in Table 41.

Table 41: List of tree species at the CFN

No	Tree species	**NO**	Tree species
1	Quercus griffithii	8	Macaranga denticulata
2	Quercus lanata	9	Dendrocalamus spp
3	Robina psedoacacia	10	Salix babylonica
4	Alnus nepalensis	11	Albizzia procera
5	Leucaena leucocephala	12	Cupressus cashmeriana
6	Dodonea viscosa	13	Albizzia spp.
7	Ficus roxburghii	14	Schima wallichii

4.2.2 Multi-purpose tree species screening trial

This trial was established with the objective of identifying through farmer evaluation the woody species that grow adequately and provide timber/poles, fuel wood, and fodder while at the same time conserve soil. A second objective was to identify fast growing hardy species for use in reforestation. The trial is super-imposed on the community forestry plantation, thereby increasing the efficient use of development resources (tree seedlings; staff and farmer time). The average heights at planting, average height after one year and height increment after one year and survival percentage of the MPTS trial at Omtekha are given in Table 42.

Table 42: First year growth assessment results of the MPTS trial at Omtekha.

Species	Ave. height at planting (cm)	Ave. height after 1 year (cm)	Ave. height increment (cm)	Survival after 1 year (%)
Robina	16.3	41.2	23.0	90
Leucaena diversipholia	80.0	76.5	-5.4*	80
Acacia arabica	51.2	101.0	49.8	100
Mahel	35.3	63.7	28.1	70
Albizzia lebbeck	36.1	28.1	-7.9*	100
Lopshe	26.9	31.9	5.1	90
Albizzia stipulata	19.9	26.9	5.1	90
Acrocarpus fraxinofolia	42.2	26.9	-15.3*	100
Melia azadarach	17.8	52.8	35.0	100
Quercus lanata	7.1	18.4	11.3	100
Morus spp.	63.5	52.5	-2.1*	80
Ailanthus excelsa	21.8	29.8	6.3	40
Poplar spp.	28.8	30.8	-1.6*	40
Cupressus corneyana	74.8	83.7	10.9	90
Albizzia procera	20.94	25.9	-0.3*	70

*(-) height increment because most trees are browsed/dieback, measurements taken of new shoot.

4.2.3 Community forestry plantation expansion

Forest resources degradation in and around villages has compelled the communities to meet their requirement for the same from distant resource-rich areas. These areas are characterised by heavily eroded soils with very little vegetation cover resulting in formation of deep gullies. With the objective to help reforest such lands, the degraded areas has been planned to be brought under community plantations involving the participation of user group communities. In addition to the 8 hectares planted in 1997-1998 about 8 hectares were planted during 1998-1999 fiscal year at Omtekha and Matalumchu. The list of species are given in Table 43 and Table 44.

Table 43: List of tree species planted in Omtekha CFP (1998-99)

No	Species	Quantity	No	Species	Quantity
1	Cupressus	1800	13	Morus indica	10
2	Robina psedoacacia	300	14	Albizzia lebbeck	10
3	Melia azedarach	477	15	Albizzia stipulata	10
4	Eriolobus indica	310	16	Acacia arabica	10
5	Macaranga denticulata	90	17	Alnus nepalensis	10
6	Leucaena leucocephala	411	18	Spondias axillaris	20
7	Dodonea viscosa	290	19	Poplar spp.	20
8	Quercus lanata	240	20	Ailanthus excelsa	10
9	Albizzia procera	140	21	Acrocarpus fraxinifolious	10
10	Leucaena diversifolia	30	22	Acacia farnesinea	10
11	Quercus gluca	300	23	Dendrocalamus strictus	20
12	Castanopsis spp.	140		Total number planted	4668

Table 44: List of tree species planted at Matalumchu CFP (1998-99)

No	Species	Quantity			Quantity
1	Cupressus	1700	15	Albizzia stipulata	10
2	Robina psedoacacia	285	16	Acacia arabica	10
3	Melia azedarach	1200	17	Alnus nepalensis	30
4	Eriolobus indica	195	18	Spondias axillaris	20
5	Macaranga denticulata	95	19	Poplar spp.	55
6	Leucaena leucocephala	400	20	Ailanthus excelsa	10
7	Dodonea viscosa	210	21	Acrocarpus fraxinifolious	10
8	Quercus lanata	360	22	Acacia farnesinea	10
9	Albizzia procera	400	23	Dendrocalamus strictus	33
10	Leucaena diversifolia	30	24	Erythrina variegata	45
11	Quercus gluca	300	25	Salix babylonica	130
12	Castanopsis spp.	140	26	Jatophus curcus	15
13	Morus indica	20	27	Quercus griffithii	270
14	Albizzia lebbeck	10	28	Schima wallichii	20
				Total	6013

4.3 Participatory Forest Management Plan for Local Use (PFMPLU)

In the summer of 1998, forestry representatives from different RNR institutions (FSD, projects, research, training) held a one day workshop at Bajo to discuss the possibility of increasing the participation of Lingmutey Chu watershed communities in the planning, management and protection of the watershed forest. This approach was termed Participatory Forest Management for Local Use (PFMLU) and would be formalised through a plan (PFMPLU). Workshop participants thought that increased involvement of communities in managing their local forests will be inevitable given RGoB's support to participatory development and given the limited staff resources available to patrol, protect and manage forest use. The Lingmutey Chu watershed could be a pilot of this approach.

Accordingly, during a 10 day period in December 1998, two multi-disciplinary PRA teams camped in the watershed and met with all six watershed communities to

identify with them their forest resources, forest use, views on the present centralised management system, and interest in developing a PFMPLU.

The dominant view of the communities was general satisfaction with the existing system, which they regarded as having improved forest cover, reduced inter-community disagreements over forest resource use, and able to provide them legally or illegally with the resources they needed. The communities raised a number of issues with which they were unhappy such as the time required for permit processing; the occasional untimeliness of tree marking and their inability to protect their local forest from legal extraction by outsiders. These issues and some suggestions have been forwarded to the concerned FSD authorities. On balance, the communities clearly preferred to continue with the present system rather than develop an inter-community PFMPLA for the whole watershed forest. They doubted that they could achieve the necessary co-operation within and between communities; and doubted whether they would see any extra benefit for the increased input that they would have to make.

Nonetheless, all villages were keen to have protection powers over their immediate forest and some villagers (more often men than women) were interested in further discussions on inter-community collaboration towards a PFMPLA, provided that FSD staff would maintain their forest protection role. The PRA team members recognise that the PFMPLU concept was probably introduced too suddenly and with inadequate explanation. This made it difficult for community members and watershed leaders to fully grasp its potential benefits as well as its potential drawbacks. With these factors in mind, BG-SRDP and Bajo staff plan to hold further more detailed discussions about PFMPLU with interested villagers. Depending on these discussions, the staff and villagers will decide whether and how to proceed further.

4.4 Activities in the Territorial FMUs

Forestry research of the centre as stated earlier had solely concentrated on social forestry research mainly due to lack of researchers. With the aim to diversify into mainline forestry, two forest management units under the Wangdue territorial division (viz. Rimchu FMU and Khotokha FMU) were identified as possible sites of research during the second national forestry coordination workshop at Taba, Thimphu.

4.4.1 Khotokha FMU

The Khotokha Forest Management Unit is situated in Bjena and Rubisa geogs of Wangdue Phodrang Dzongkhag. It covers an area of 9407 hectares and ranges from 2300m to 3785m in elevation.

The dominant tree species in the FMU is blue pine (*Pinus wallichaina* A. B. Jackson) It has many uses in Bhutan. Besides being the most important species for timber, poles, chams and firewood, blue pine forest are also used for collecting leaf litter for farmyard manure.

The present silvicultural practice in conifer forests largely rely on natural regeneration to restock the logged over forest. However a lack of regeneration is observed in most conifer forest in Western Bhutan (Norbu, undated). Grazing is the

frequently cited reason for this while forest floor cover (slash) and bamboo growth (weed) are also equally important factors impeding regeneration (Richen and Godi, 1995; Norbu and Desmond, 1999).

As such a trial is proposed in the logged areas with the aim to assess the regeneration status in the blue pine forest of the West-central region and also strive to ascertain the effects of the above factors on regeneration.

To this end the site was visited by a team from the RNRRC, Bajo and Wangdue territorial division and a research proposal written up which has been circulated for comments.

4.4.2 Rimchu FMU

Rimchu Forest Management Unit under Punakha Dzongkhag has a gross total area of 212 hectares with gentle to moderately sloping topography. The forest type is sub-tropical cool broadleaf and the main species include *Michelia sp., Castonopsis sp., Quercus sp., Schima wallichii*. Logging has occurred since 1996 in accordance with a Working scheme prepared as an interim measure to meet the raw material requirements of the local population, urban centres of Punakha and Wangdue and the sawmill at Lobesa. These logged areas are characterized by profuse growth of *Macaranga sp.* with almost no other species regenerating.

A trial to study the effects of logging on regeneration, probable species of recruitment was proposed. A simultaneous study to find out commercial uses for the *Macaranga sp.* also need to be done to capitalise on the immense regeneration of this species in the logged areas.

4.5 Conclusion

The forestry research program though constrained by the lack of researchers has made commendable progress especially in social forestry sub-program. With the two FMUs identified for research at the Second National Forestry Coordination workshop, it is hoped a modest step into mainline forestry research can also be achieved by the centre.

5 SYSTEMS RESOURCE MANAGEMENT

5.1 Community Based Natural Resources Management (CBNRM)

CBNRM research in the Lingmuteychhu watershed was continued during 1998-99. Interventions which aimed at addressing the problems recognized during the diagnostic survey were implemented under each research theme. This report presents the activities and results of 1998-99.

5.1.1 Crop Production and Management Research

5.1.1.1 High altitude rice variety selection

This trial was carried out to address the low rice yield problem advanced by farmers during the participatory needs assessment in the watershed particularly in Limbukha and Dompola villages (1800-2170m asl). The objective was to identify suitable high yielding rice variety with farmer participation.

Seeds of 13 rice varieties were provided, from the research centre, to the cooperator farmer. The cooperator farmer was identified on a voluntary basis from the households in a village. The trial was placed in Limbukha village. Nursery was raised by farmer under the guidance of researcher. Each variety was planted to 10 rows of 5 m long. During the crop growth stage co-operating farmer/researchers invited other farmers to give their views and identify the potential varieties.

Out of 13 varieties, farmers based on their criteria selected six varieties as promising for further evaluation in 1999. These are : Yunan-13, Yunan-16, Hexi-24, Kunming-217, Kunming-830 and Chummro.

5.1.1.2 Rice crop-cut results in Limbukha

The crop cut exercise was aimed at establishing benchmark yield for Limbukha and also to assess incremental yield loss with delayed transplanting caused by rice-potato cropping sequence. Potato-rice pattern is a relatively new cropping pattern in the wetland. This pattern is rapidly expanding since potato is the main cash crop for farmers . Adoption of this pattern has resulted to late planting of rice thus reducing the rice yield. The crop cut was done to assess the yield loss.

The output of the crop cut exercise is presented in Table 45. The results indicated that there is yield reduction or loss as the transplanting time is delayed. A loss of 15% is estimated if transplanting time is delayed till second half of June and after June the loss can be as high as 30% (1.37 t/ha). Most farmers are seen to transplant around second half of June thus losing about 15% of rice yield. Income from potato should cover the lost opportunity of growing wheat/buckwheat and the loss in rice yield. Crop budget analysis will be conducted to look into the economics of this change.

A change in the cropping pattern has not only affected the farmers of Limbukha but has also impacted other farmers who are downstream in the watershed, through reduction in the availability of irrigation water for rice transplanting. This is particularly

true in the case of a downstream village Dompola. Due to late start of planting by Limbukha (upstream) farmers the availability of water for Dompola has been severely reduced.

Table 45 Rice yields obtained across transplanting periods in Limbukha

Farmer	Transplant date	Harvest date	Variety	Yield (t/ha)
Ap Kencho	17.04.98	03.11.98	Shengnab	4.36
Zaam	01.05.98	03.11.98	Shengnab	4.58
Nim Dorji	14.06.98	-do-	Shengnab	4.17
Namgay Dorji	16.06.98	02.11.98	Bomdelling	4.13
Chencho	17.06.98	03.11.98	Shengnab	3.97
Bara Wangdi	18.06.98	04.11.98	Bomdelling	3.33
Kencho Wangdi	21.06.98	02.11.98	Shengnab	3.91
Kinga	22.06.98	04.11.98	Shengnab	4.53
Nam	23.06.98	05.11.98	Shengnab	3.59
Phuntsho	26.06.98	02.11.98	Shengnab	2.93
Y. Bida	26.06.98	03.11.98	Shengnab	3.47
Am Khandu	27.06.98	02.11.98	Shengnab	2.60
Ap Kinley	28.06.98	04.11.	Shengnab	4.10
Bara Wangdi	29.06.	04.11.	Bomdelling	4.14
Pasang Wangdi	07.07.	04.11.	Shengnab	3.32
Tandin dorji	09.07.	03.11.	Shengnab	2.97
Kencho Dorji	11.07.	06.11.	Bomdelling	2.60
Am Bida	13.07.	04.11.	Gyembja	3.30
Ap Wangchuk	16.07.	05.11.	Shengnab	3.05
Average yld.				**3.63**

5.1.1.3 Assessment of Chummro as upland rice variety

Nabchhe village has a shortage of irrigation water and some wetlands have not been cultivated. After discussing with the farmers, it was decided that upland rice that sustains on rainfall and soil moisture will be tried. For the first year, it was agreed that research will provide seeds of variety Chummro and farmers will maintain their own seeds for the coming years. Farmer cooperators managed the crop following their usual practices. Researchers only monitored the trial at different crop stages.

Chummro is not a high yielding variety, yet it yielded up to farmer's satisfaction. From an area of about 1400m^2, it yielded 196 kg (1.4 t/ha) which is a good average for an upland rice crop. Rainfall, albeit not recorded, was presumably sufficient and fairly evenly distributed. Some of the farmers' feedback on the variety are:

- Good tillering compared to their local variety.
- Length of panicle longer than the local variety.
- Red pericarp which is preferred by the farmers.
- Thin husk cover and less milling losses compared to local variety.
- Crop doing well in both conditions i.e. in wetland and also in upland.

5.1.1.4 Maize variety evaluation by farmers

Maize is a staple food crop of Nabchhe farmers. They reported that their local maize variety has problems like lodging, decreasing yield, taller plants and barrenness. Improved maize varieties from RNRRC Khangma were evaluated to identify the suitable high yielding variety.

The trial was established with two farmers. Seeds of three test varieties were provided. Farmers' management practices were followed. The trial was established at an altitude of 1700m. A matrix ranking method was used to seek farmers' views on variety performance. A local variety was included for comparison. Varieties were: Pool 9B C1, Suwan 8528 and Palmirah 8528.

The crop cut results are presented in Table 46 . Varieties Palmirah and Pool 9B C1 yielded higher than Suwan and the local. The yield figures reported here are from one crop cut per variety only.

Table 46. Maize yields and characteristics

Variety	Yield (t/ha)	Characteristics
Palmirah	6.3	White flint
Pool 9B C1	5.8	Yellow flint
Suwan	1.9	Yellow flint
Local	5.4	Yellow flint

In a matrix scoring exercise with farmers, Pool 9BC7 scored the highest overall scoring among five maize varieties. Variety, Palmirah, though yielded highest ranked as the second best performer. Yield is not only the criteria used for selection of a variety. Farmers look at a host of traits to finally accept a variety. Palmirah was discounted for its unsuitable color (white flint) for making beaten maize which is an important product.

Farmers selected Palmirah 8528 and Pool9 BC1 as acceptable varieties. Also besides the collaborating farmers many neighbouring farmers showed keen interest to grow these varieties in the next season. A post-trial adoption study will be pursued to monitor and validate farmers' assessment.

5.1.1.5 Post-trial monitoring in wheat

In 1997-1998, trials to improve wheat production were conducted in the watershed. Seeds of new wheat varieties were also made available to farmers. At the end of the season farmers appreciated the output from the trials. To evaluate and validate farmers feedback on the trial, a post-trial monitoring exercise was conducted.

All the trial cooperators were observed to continue to grow those improved wheat varieties. They have also shared the seeds to other interested farmers. Farmers reported their preference for variety BK-II than BK-I. Farmers mentioned of yields ranging between 2.25-2.70 t/ha from BK-II and 1 ton /ha from BK-I. Besides yield farmers also noted that BK-II has attractive color and is easy to thresh. The only negative trait in BK-II, according to farmers, was that it has shallow rooting which makes the plant easy to up-root. The local extension agent has also provided seeds

of BK-II for promotion and obviously its coverage was encouraging in the villages of Limbukha, Dompola, and Omtekha.

5.1.1.6 Documentation of winter vegetables

A farmer participatory survey on winter vegetable production in the Lingmuteychu watershed was conducted with an aim to identify production potentials and constraints. This report presents highlights of the survey. Detailed report is published separately as a technical report.

Table 47 Problems and opportunities of vegetable cultivation in Lingmutechu.

Village	Problem	Opportunity	Remarks
Limbu-kha	▪ Red ant damage in potato ▪ High humidity causes seed potato storage problem ▪ Use of poor quality potato seed ▪ Blight in chilli	▪ Potato after rice has good market in May-June when both imported and local potatoes are low in supply ▪ Good for Brassicas	▪ H/holds have well developed kitchen garden. Self-sufficient for home consumption
Domp-ola	▪ Damage by insect pests ▪ Blight in chilli	▪ Growing cole crops of cabbage, cauliflower, and broccoli; also carrot and tomatoes	▪ H/holds have well developed kitchen garden ▪ Self-sufficient in home consumption ▪ Chilli is the main cash crop
Nab-chhe	▪ Poor water supply for drinking and irrigation ▪ Blight in chilli	▪ Growing grain legumes esp. beans ▪ Tomato and asparagus??	▪ No well developed kitchen garden ▪ Shortage of vegs for home consumption
Mata-Lumchu	▪ Red ant damage in potato ▪ Blight problem in chilli ▪ Insects in brassica	▪ Early maturing potato after rice ▪ All high value veg. Crops	▪ Well developed kitchen garden ▪ Self-sufficient in vegetables

5.1.2 Crop-Livestock Interaction (Feed and Fodder)

Based on the winter fodder trial results of 1997-1998, evaluation of winter fodder was continued with wider coverage and participation of farmers in the watershed. Below are some of the observations and results on fodder research.

5.1.2.1 Evaluation of winter fodder mixture

Oat was identified as one of the most acceptable winter fodder species by watershed farmers. However, since oat is grown after paddy it is likely that oat will deplete soil fertility and eventually affect rice yield. It is thought that by growing fodder legume mixed with oat the above problem may be curbed. The aim of the trial was to find the best mixture combination.

Farmers were selected by consulting Tshogpa, and mixed seeds were distributed in legume to grass ratio of 1:3. Technical advice was given to farmers at the time of seed distribution. The trial was managed by farmers. Crop cuts were taken in random to find out fresh biomass. Seeds were sown in December - February.

Farmer usually start feeding green fodder from March to June to selected animals like lactating cows, calves, draft bull and horses. The best mixture combination was oat with Lathyrus. The crop-cut result showed 60 t/ha fresh weight from oat and Lathyrus mixture and 40 t/ha from oat and vetch mixture. The plants were cut at the height of 1-1.5 m. Although no botanical composition was done but through visual assessment the oat and Lathyrus mixture was better. However, after first cut there was no re-growth of legume species. Farmers thought legumes in the mixtures as some new kind of weeds despite earlier discussions. The function of legumes in improving soil fertility was explained to the farmers.

In a post-trial monitoring exercise it was observed that the number of farmers growing winter fodder is increasing. Within two years Limbukha villagers have taken oat cultivation at household level. Some have even started to produce their own seeds. Farmers noted that oat has solved some of their fodder shortage problems and saved their time in fodder collection. Oat is preferred for its fast growth, more number of cuts, high bio-mass and better palatability than wheat.

5.1.2.2 Monitoring community breeding bull management

Nabchhe farmers expressed, during the diagnostic survey, their interest to increase the population of mithun cattle breed. They reported of not being able to own a breeding bull and requested for help to procure one. Based on their request a mithun breeding bull was arranged in April 1999 through the financial assistance from the Bhutan-German Sustainable RNR Development Project (BGSRDP) in Lobeysa.

The community has constructed a bull-shed and has agreed on the feed contribution and service fees. One *langdo* of unproductive government land was brought under improved summer pasture for the bull. Researchers have helped the community with appropriate pasture species and techniques of cultivation. Monitoring will be continued in the future.

5.1.3 Integrated Plant Nutrient System Research

Research and development work in soil fertility management through Integrated Plant Nutrient System (IPNS) began on- station at the RNRRC Bajo in 1995. In May 1997, a Participatory Rural Appraisal (PRA) was done in the Lingmutey Chhu watershed and three IPNS sites were selected where a research has begun in relation to IPNS in collaboration with the Sustainable Soil Fertility and Plant Nutrient Management Project (SSF & PNM). This work is being continued as it is one of the important research themes in CBNRM.

The overall objective of the IPNS Site program is to enable research and extension to work with farmers to improve their soil fertility management systems using an IPNS approach to improve the productivity of the land without depleting soil resources. The details on the methodology and processes are reported separately as CBNRM technical document. This report provides results of the IPNS research in the watershed.

5.1.3.1 Effect of NPK as basal and split application of urea in rice

Rice is the main staple food of farmers and communities in the Lingmutey Chhu watershed. Many farmers produce enough for their family, but there are also farmers who do not have sufficient rice for their family.

During several discussions with the watershed farmers, they reported yield decline in rice. The trend is greater in the fields far away from their homestead and this was attributed to soil fertility management. Farm yard manure is never applied to these fields due to its limited availability and the distance of the fields. Urea is top-dressed at the rate of 30-60 kg/ha after weeding. The soil analyses from the test farmer fields showed that the field is low in both P and K, though moderate in N. A fertiliser trial was conducted in the area:

- to determine, whether there is a yield and economic benefit in applying NPK basal dressing in addition to farmers' practices, and
- to determine whether there is a benefit in splitting the farmer practices of N top dressing between a basal dressing and a top dressing.

The trials were done in Wangjokha and Dompola. Each farmer was taken as a replication. Three plots of 85m^2 each were used. Fertilisers needed for the trial was provided by the researchers. Observations were made at different stages.

Crop cuts were taken during harvesting and the results are shown in the table. At harvest farmers noticed yield differences between plots. Farmers' practice of urea top-dressing @ 60 kg/ha yielded only 4.10 t/ha. When this same amount of urea was split in two applications, one as basal and the other as top-dress the yield increased to 5.0 t/ha. In addition to farmer's practices of applying urea as topdress, when 200 kg/ha of suphala containing NPK was applied the yield increased to 6.20 t/ha.

Table 48 Grain yield of rice under three levels of fertilizer management

Treatments	Yield (t/ha)
T_1 (urea basal dressed @ 30 kg/ha + urea top-dressed @ 30 kg/ha)	5.00
T_2 (urea top-dressed @ 60 kg/ha + suphala 200 kg/ha as basal dressed)	6.20
T_3 (urea top-dressed @ 60 kg/ha)	4.10

Economic analysis of fertiliser used in rice

Table 49 gives the input and output prices applied in the economic analysis. The fertiliser prices are the retail rates and transportation charge is not calculated. The price of paddy is calculated based on the rate farmers received in the village.

Table 49 Rates of input and output used in economic analysis.

Sl. No	Input/output	Unit	Price (Nu/unit)
1	Urea	Kg	4.5
2	Suphala	Kg	7.62
3	Rice	Kg	8.00

Data source: Extension diary and farmer interview

Table 50 Partial Budget for fertiliser used in rice

	T_1 (urea split)	T_2 (NPK basal + urea top-dressed)	T_3 (farmer practices)
Grain yield (t/ha)	5.00	6.20	4.10
Gross field benefit Nu./ha	40,000	49,600	32,800
Cost of urea Nu./ha	117.50	117.50	117.50
Cost of suphala Nu./ha	0	610	0
Cost of labour Nu/ha	300	300	150
Total cost that vary Nu/ha	417.5	1027.50	267.50
Net benefit Nu/ha	39,582.50	48,572.50	32,532.50

Data source: Crop cut results.

The results (Table 50) from the partial budget showed that application of urea top-dressed @ 60 kg/ha with NPK basal dressed @ 200 kg/ha is more profitable with net benefit of Nu.48,572.50/ha than applying only urea top-dressed @ 60 kg/ha in two splits with net benefit of Nu. 39,582.50/ha. Also split-applied urea is more profitable than a single dose top dressing of urea.

Table 51 Marginal rate of returns

Treatment change	Marginal benefits Nu/ha	Marginal costs Nu/ha	Marginal rate of returns %
T3 ⟶ T1	7050	150	47
T1 ⟶ T2	8990	610	15

With the change of treatment T_3 to T_1 the marginal benefit is Nu. 7050/ha and marginal cost is Nu. 150/ha with marginal rate of returns 47%. With the change of treatment T_1 to T_2 the marginal benefit is Nu. 8990/ha and marginal cost is Nu. 610/ha with marginal rate of returns 15%.

Difference in the yield is very significant from the results, but the results are only from one site. It might be worth testing further in the same location for confirmation and fine-tuning the rate of farmers' fertiliser use. There are two options for follow-up: (a) the same treatments could be kept in the same plot to get residual effect and (b) increase number of replication by including other farmers to diversify the site.

5.1.3.2 Evaluation of soybean varieties

Farmers grow soybean, but not on a large area due to lack of seeds. Their own seeds are either affected by insects or consumed. RNRRC Bajo had some seeds of promising soybean varieties from RNRRC Khangma. A trial was hence implemented with the objective to identify the most acceptable high yielding soybean variety.

Three soybean varieties were tested in two different IPNS sites. Each variety was compared with the local in all sites. Seeds were sown in mid April. This was a farmer designed and farmer managed trial. Researchers monitored the trial at different stages. Traits of the varieties are given in Table 52.

Table 52 Characteristics of soybean test varieties and the local

Varieties	**Seed size**	**Seed colour**	**Maturity (days)**
AGS 313	Small seeded	Greenish	160
AGS 327	Big seeded	Whitish	175
AGS 286	Big seeded	Whitish	175
Local	Medium seeded	Brownish/whitish	175

The harvesting dates varied depending on the variety. AGS313 matured earlier and was harvested in the first week of September. AGS327 and AGS286 were harvested in the last week of September. AGS313 did well in Dompola . AGS327 did not germinate in the same site. In Nabchhe, AGS327 and AGS286 performed very well.

Yield is the most important criterion for farmers' assessment and according to the farmer the three soybean varieties yielded as much as the local one. It was not possible to do a crop cut and the yield comparison between varieties was done from

ten (10) soybean plants of both improve varieties and the local. The yields were 498gm and 490gm respectively suggesting no difference in yield.

The varieties AGS 327 and AGS 286 are likely to be adopted by the farmers. AGS 286 is an early maturing variety and this allows farmers to fetch high price in the market when sold as green boiled. Farmers also confirmed that soybean cultivation improves soil structure and they relate this to rotting of leaves. Since AGS327 and AGS286 did well with certain good criteria which fulfilled some of farmers' criteria for assessment, they will further be tested.

5.1.3.3 Effect of inorganic fertilizer application in chilli

Chili is one of the main cash crops in the watershed. However, because of the wilt disease (chilli blight) most of the farmers get very low yield or none at all. During several discussions with farmers, they expressed the blight problem as a major one in the area. Some farmers at Dompola thought that the problem might be related to nutrient deficiency. Soil analysis showed that the field is very low in P and medium to low in K, but N is moderate. Farmers grow chili applying FYM as basal and urea topdressed after the first weeding. Based on the soil results farmer discussions, a balanced fertiliser trial conducted to test the effect of NPK applied as basal on chili growth, yield and blight incidence.

There were three treatments (Table 53) with an area of 30 m^2. Fertilisers needed for each treatment were provided, however in future if farmers adopt this technology, they will have to bear the expenditure on fertilisers.

Table 53 Yield and severity of chili blight by treatments

Treatments	Yield (t/ha)	Blight incidence
T_1 FYM farmer practices	6.00	None
T_2 Urea top-dressed @ 100 kg/ha + FYM	11.33	1/4 of the area infected
T_3 Suphala basal @ 200 kg/ha + urea top-dressed @ 100 kg/ha + FYM	10.00	1/2 of the area infected

During all different growth stages of the chili, the performance was always better in the plots where the fertiliser was used. In terms of yield, the control plot T_1 yielded only 6.0 t/ha, T_2 yielded 11.33 t/ha and T_3 yielded 10.0 t/ha of green chilies. The chili blight problem was more severe in T_2 and T_3. If the plots were not affected by the blight, the yields could have been much higher.
Farmer associated high wilt severity in these treatments to good canopy cover which reduced light reaching the ground.

Economic Analysis for fertiliser used in chili

Table 54 Rates of input and output used in economic analysis

Input/output	Unit	Price (Nu/unit)
Urea	Kg	4.5
Suphala	Kg	7.62
Chili	Kg	22.50

Data source: Extension diary and farmer interview

Table 54 gives the input and output prices applied in the economic analysis. The fertiliser prices are the retail rates and transportation charge is not calculated. The price of chilli is calculated based on the rate farmers received in the market. The price ranged between Nu.15-25 per kg. chilli. The average price is Nu. 22.5/kg of green chilli.

Table 55 Partial Budget for fertiliser used in chilli.

	T_1	T_2	T_3
Chili yield (t/ha)	6.00	11.33	10.00
Gross field benefit Nu/ha	112,500.00	254,983.75	225,000.00
Cost of urea Nu/ha	0	117.5	117.5
Cost of suphala Nu/ha	0	0	610
Cost of labour Nu/ha	0	150	300
Total costs that vary Nu/ha	0	267.50	1027.50
Net benefit Nu/ha	112,500	254,715	223972.50

Result from the partial budget (Table 55) showed that application of urea top-dressed @ 100 kg/ha (T_2) is more profitable with net benefit of Nu.254,713.75/ha than applying both suphala as basal @ 200 kg/ha with urea top-dressed @ 100 kg/ha (T_3) with net benefit of Nu. 223,972.50/ha.

Table 56 Marginal rates of returns

Treatment change	Marginal benefits Nu/ha	Marginal costs Nu/ha	Marginal rate of returns %
T1 ⟶ T3	112,500	1027.5	109.5
T3 ⟶ T2	29982.50	760	39

With the change of treatment T_1 to T_3 the marginal benefit is 112,500 Nu/ha and marginal costs is 1027.5 Nu/ha with marginal rate of returns 109.5%.
With the change of treatment T_3 to T_2 the marginal benefit is 29,982.50 Nu/ha and marginal costs is 760 Nu/ha with marginal rate of returns 39%.

Farmer's nutrient management practices in chilli differ in both quantity used and methods/timing of application from the research recommendations. This does not mean that farmer's way of doing would not be effective.

5.1.3.4 Evaluation of trash line in maize farming to control soil erosion

Land topography in Nabchhe ranges from steep (65%) to gentle slopes (40%). Growing crops on a land with slope of >65% may not be a sustainable land use practice and farmers are terracing their land. Terracing helps in reducing soil erosion, and the formation of such terraces could be laid out with maize stover. This study was to test the utility of maize trash lines in terracing and thereby reducing soil surface run-off and erosion.

Researchers laid out contour lines with the help of A-frame along with farmers and extension staff. The farmer-cooperator planted maize along and between the contour lines and fully managed his crop. After the crop is harvested, maize straw left in the field was collected and kept along the contour lines by farmer. Contour lines will remain as such as cultivation practices are followed year after year.

Since farmers' long term objective is for terracing their land, the maize trash line alone may not be very strong for the formation of risers/bunds. This issue was discussed with the farmers and they want to try some fodder species on one contour line. The other suggestion farmers made was to keep stones on the contour line. Research will identify potential fodder species for use on the trash-lines.

5.1.3.5 Adaptation study of fodder species

Livestock production in Bhutan is a major enterprise and is well-integrated component of the traditional farming system. However, large areas of grazing land and forest areas are government owned, with the result that livestock owners will not improve the land without their title to the land. Thus there is always an imbalance in livestock population and fodder production especially in winter. In this regard, farmers expressed their interest in trying some winter fodder, which will help them to solve their winter fodder shortage.

Researchers provided the seeds of Sudan grass and alfalfa. Both the species germinated very well. However, few weeks after germination, alfalfa slowly disappeared. This species is very specific in it's rhizobia requirement and inoculation is absolutely necessary. Since inoculation was not done properly this might be the reason for it's disappearance. Alfalfa seeds were sown mixed with soil from the centre where inoculated seeds were sown in the past.

Sudan grass did very well and a number of cuttings were done. However, this grass is an annual one and the farmer wants to replace it with a perennial one. Napier grass is suggested. Farmers have two objectives in this trial; first for fodder production and the second to control surface soil run-off. Since Sudan grass is not a suitable species to fulfil farmer's both objectives, it is important to find out a perennial species which will match farmer's. Sudan could be a good fodder species for one season fodder production only.

5.1.3.6 Farmer training on crop nutrient management

A farmer training was conducted to make them aware on different nutrients needed by plants, its sources and use, and different losses from the soil.

The training was conducted in collaboration with the RNRRC Bajo, SSF and PNM Project staff and Dzongkhag extension staff. It was a one-day training. The brief presentation on each objective was followed by discussions. After the presentation and the discussions, post training evaluation and review was done. Then participants visited the test farmer activities in the area.

Observation and discussion

- In Nabchhe there were 14 farmer participants (10 women and 4 men);
- Participants found the training content very useful in their day to day farming activity;
- On showing Diancha as an example of legume crop with nodules, a number of farmers showed their interest in growing this crop as green manure in wet land;
- In Wangjokha there were 12 farmer participants (6 men and 6 women);
- Farmer participants commented that such kind of training was the first time they attended in the field of agriculture and they found the training very useful;
- They reported that it is the first time they hear about nodules on bean and pea adding nutrients to soil, which was not known to them earlier;
- As an outcome of the training, 6 farmer participants proposed to try a balanced fertiliser trial in their wheat and mustard crop as the rates they were using is either very high or vice versa.
- Over all this training was found to be a good starting of the research on Integrated Plant Nutrient System in the area. It allowed farmers to get familiarised with the concept of IPNS and the related on going activities.

5.1.3.7 Effect of improved management of inorganic fertilizer in spring rice crop

Yields from the first crop of rice in Rinchengang area were reported to be very low. This issue was discussed in the Fifth Regional Workshop held at the RNRRC Bajo in January 1999. Crop cut results from rice first crop in 1997 showed that the yield was only 2.25 t/ha.

Farmers of this village use their fields very intensively (three crops per year) with limited soil nutrient inputs. While inorganic fertilizer use is common in the area, unbalanced use (only single nutrient urea), poor timing (not enough in early crop growth) and inefficient method of application are found to be practiced. An improved use of fertilizer trial in rice first crop in Rinchengang area was conducted:

- to see the effect of adding 25 N:30 P:0 K Kg/ha as a basal with 25 Kg N/ha as top dressing (Research Recommendation)
- to see the effect of split application of farmer practice of urea application as top dressing and basal.

This trial was done with eight farmers in Rinchengang. Three treatments were used (Table 57) and plot size for each treatment varied from farmer to farmer depending on the size of their terraces. Amount of fertilizers needed for each treatment was provided by the research center. Observations were made at different crop stages and crop cut of 10 m^2 per treatment was done at harvest.

During different growth stages of the crop, differences between the treatments were not observed. However, prior to harvesting there was some difference in the length and heaviness of the panicle between the treatments in two replications. Crop cut results from all the replications are shown in Table 58. Rice variety in all the replication is No 11.

Analysis of variance indicated significant differences among treatments. Improved farmer practice of urea application (T2) and the recommended fertilizer practice (T3) gave significantly higher grain yield than farmer practice of urea top dressing in single application (T1) (Table 59). Changing from T1 to T2 the yield increased by 29% or 1.3 t/ha.

The analyzed result suggest that there is a good potential to substantially improve the spring rice yields by simply improving the management of the urea fertiliser that farmers are already applying in single application. However, greater improvements are possible from the use of balanced fertilisers i.e. NPK in addition to urea top dressing. Farmers are aware of the benefit of applying fertilisers, but their affordability is rather limited.

Table 57. Treatment details

T_1	Farmer practice of urea top dressing in single application (45 kg urea/ha).
T_2	Improved farmer practice of urea application in split application between two equal dressings (one as basal and one as top dressing at tillering)
T_3	Recommended practice of 25N:30P:0K Kg/ha as basal plus 25 kg N/ha as top dressing.

Table 58. Yield based on crop cut result

Farmers	Treatments	Yield kg/10m^2	Moisture at harvest (%)	Yield (t/ha)
	T1	5	23	4.48
Dorji	T2	5.8	23	5.19
	T3	6	23	5.37
	T1	4	21.1	3.67
Rinchen	T2	5	21.1	4.59
	T3	7	21.1	6.42
	T1	5	22	4.53
Ap Lengo	T2	6.8	22	6.17
	T3	8	22	7.26
	T1	4.5	22	4.08
Chado	T2	6	22	5.44
	T3	5	22	4.53
	T1	6	24	5.30
Galay	T2	7	24	6.19
	T3	6	24	5.30
	T1	5	22	4.53
Tshering	T2	6.2	22	5.62
	T3	7.8	22	7.07
	T1	5	21	4.59
Ugen	T2	7	21	6.43
	T3	6	21	5.51
	T1	4.8	21	4.41
Chalom	T2	7	21	6.43
	T3	6.5	21	5.97

Table 59. Grain yield under three different treatments

Treatment	Yield (t/ha)
T1 (Farmer practice)	4.45 a
T2 (Improved farmer practice)	5.76 b
T3 (Recommended practice)	5.93 bc
C.V (%)	12.5
LSD	0.72

5.1.3.8 Evaluation of winter Hairy Vetch as cover crop in dryland farming

Most of the fields in Nabchhe are kept fallow in winter. These steep lands when kept fallow become vulnerable to soil erosion by rain water, strong wind and domestic animal movements. Results from the on-station evaluation of hairy vetch as cover crop proved successful with good bio-mass production from 2-3 cuttings. The vetch

can be used as fodder and for improvement of soil fertility. The purpose of the trial was to find out if hairy vetch is suitable to use as cover crop in winter in dry land farming system in Nabchhe.

The trial was conducted with one farmer in Nabchhe. One kg of seed was provided with technical guidance. Sowing was done in the first week of November without any fertilization. The trial area covered 20 m^2 . Germination was about 60% - 65%. This low germination percentage could be due to drought problem during germination. Crop vigor improved with the start of the rainfall. Nodulation was good. Three cuttings were done and each cut gave 12-15 kg biomass.

5.1.3.9 Dhaincha (*Sesbania aculeata*) as pre-rice green manure

Proposed changes to the fertilizer supply and distribution system in Bhutan in accordance with Government policy to end subsidies will mean that fertilizer prices will double over the next 5-10 years. In such circumstances the use of green manure may become more attractive to farmers and is more likely to be adopted. Thus this adaptive on-farm trial cum demonstration was planned. Dhiancha as green manure from the on-station trials showed that there is an yield increase of 20-30%.

This trial was done with one farmer each in Wangjokha and Nabchhe. At Nabchhe the trial was merely planned to see if dhaincha could be at all grown at an altitude of 1800 m. Three kg seeds were sown in an estimated area of 40 m^2. In Wangjokha, 30 kg seeds were sown in 400 m^2. In both the sites sowing was done in the first week of April.

Germination was good with 70% - 80% in both the sites. Biomass from 60-70 days old plant was incorporated in the last week of June. The plants showed 80% - 90% nodulation with 50% - 60% effective nodules at the time of incorporation. The plant height measured 30-40 cm at incorporation. Observations on the performance of the subsequent rice crop is underway.

It is a general practice that, a technology with short term results tend to attract more adopters. On the contrary, to get results from using dhaincha as green manure needs certain years and normally it is less attractive to farmers. In such case, collecting and testing of other potential leguminous species which have short term results in the form of either grains, fodder etc. besides soil improvements would be an important area to be looked into.

5.1.3.10 Effect of improved management of inorganic fertilizers

This trial was done to see the effect of using fertilizers (recommended rate) in wheat and mustard. Treatments were as follows:

- T_1 Farmers' practices with no inorganic fertilizer application
- T_2 Recommended practices with 60N:40P:20K kg/ha in wheat and 60N: 40P: 0K kg/ha in mustard

The trial was done with six farmers from Wangjokha village. Out of six farmers one tried in mustard and the other five in wheat. A crop cut per treatment was taken during harvesting and the yield data from the crop cut results are presented in Table

60. During different growing stages of the crop, differences were observed between treatments. Crops in T_2 looked healthier, taller and more green compared with crop stand in T_1. However, statistical analysis indicated that the mean yields of the treatments were not significantly different (Table 61). The mean yield was, however, higher with T2.

Table 60 Wheat and mustard crop yields based on crop-cut results

Farmer name	Treatments	Yield kg/10m^2	Moisture at threshing	Yield (t/ha)
Ap Daw	T1	2.4	11.2	2.42
	T2	3	11.2	2.80
Am Nima	T1	1	8.1	1.04
	T2	1.2	8.1	1.25
Ap Lhatu	T1	2.1	7.5	2.21
	T2	3.9	7.5	4.10
Am Sangay Om	T1	1.6	9.5	1.65
	T2	2	9.5	2.06
Am Lotey	T1	1.5	8.5	1.56
	T2	1.8	8.5	1.87
Ap Kencho Dorji (mustard)	T1	1.4	10	1.43
	T2	2	10	2.05

Table 61 Analysis of variance

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Rep.	4	4.9866	1.2467	5.05	
Trt.	1	1.0240	1.0240	4.14	0.111
Residual	4	0.9884	0.2471		
Total	9	6.9990			
C.V (%)	23.7				
LSD	0.87				

Economic analysis is needed for fertilizer trials and for doing that data on prices of wheat and mustard, cost of labour applying fertilizer and cost of transportation of fertilizers are needed. These data need to be collected from the farmers.

5.2 Integrated Pest Management

5.2.1 Screening chilli lines for resistance to *Phytophthora* blight

Phytophthora blight caused by *Phytophthora capsici* threatens chilli cultivation in many parts of the country since 1994, when the disease first sporadically affected the Bhutanese chilli production. Some of the reasons for higher incidence of blight were: high planting density, improper drainage systems, and use of infected seed/ seedlings on traditional flat plots. Since 1995 several on-station and on-farm researches to address the problem have been done which led to the present recommendation of raised bed, proper plant spacing, good drainage system along with the use of healthy seed/ seedling (s).

IPM pilot village approaches were introduced in several villages throughout the country to work on the development of an appropriate IPM package to manage the disease. Although the raised beds with proper plant spacing and irrigation management recommendations do control the disease in some places, it has failed in many parts of the country. Hence a program was initiated to breed *Phytophthora blight* resistance in Sha Ema, in collaboration with AVRDC in Taiwan.

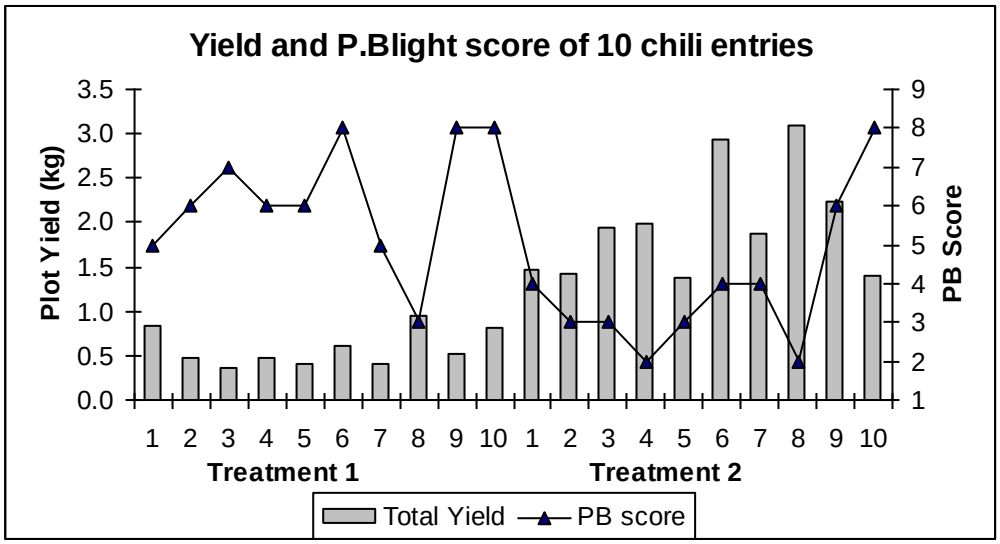
The short-term objective was to evaluate the backcross-derived lines of Sha Ema for yield, earliness, resistance to Phytophthora blight, and fruit quality acceptable to the local consumers. In the long run, it aims to develop resistance to Phytophthora blight in all the popular Bhutanese varieties through backcrossing and introgression.

The seeds of 10 entries, 7 backcross-derived lines (Table 62) along with a resistant check, a susceptible check, and local check (Sha Ema) were sown on the 9th March 1999 in the nursery bed of a screen house. A thin layer of straw was burnt over the seedbed before sowing to sterilise the soil. Seeds were sown at a spacing of 2-cm seed to seed and 15 cm row to row.

The nursery was irrigated using a watering can every day. The seedlings were transplanted in the field on 5th May 1999 as per the treatments. Treatment 1 was the traditional flat bed method with close plant spacing of approximately 20 cm X 15 cm. Treatment 2 was the recommended method of raised bed (1 m wide, 30 cm high, 5 m long or more) with plant spacing of 50 cm X 50 cm (Figure 4). Data were recorded for various horticultural characteristics like days to anthesis, days to maturity, fruit type, fruit length, width, yield and fresh plant biomass. Reaction of the entries to *Phytophthora Blight* was scored on a scale of 1-9 using simple plot observation design.

Figure 4 Traditional practice and recommended practice
Figure 5 Yield and *Phytophthora* blight score of 10 chilli entries.

All the entries produced higher yield in the recommended planting method of raised bed with proper plant spacing (Figure 5). In the traditional planting method, entry No.8 produced the highest yield followed by No.1 and No.10 (the local Sha Ema). No. 8 also produced the highest yield in treatment 2. In both the treatments, *Phytophthora* blight infection was less in entry No.8. This owes to the fact that it was the resistant check with 25% resistance to *Phytophthora capsici*. Entry 10 (the local Sha Ema) and entry 9 had the highest incidence of *Phytophthora* blight in both treatment 1 and treatment 2. Entry 9 was highly susceptible because it was the susceptible check var. PBC 390 (highly susceptible to *Phytophthora capsici* Race 3). Data on location, experiment, yield and other phenotypic traits were also



collected as shown in Table 63.

Of the 10 backcross-derived lines, entry 8 was found to be resistant to Phytophthora blight in both the treatments. In general less incidence of Phytophthora blight and higher yield was observed on the recommended raised bed plots when compared to the traditional flat plots. None of the entries (other than entry 10, Sha Ema) were acceptable to the local consumers, as the fruit type and pungency were not comparable to Sha Ema (Figure 6). The results have been sent to AVRDC, Taiwan for further improvement in the breeding programme. In the future, a chilli blight action plan needs to be developed at the national level so that resistance breeding for all the other important/popular land races of chilli could be done to control Phytophthora blight.

Figure 6 Fruits of the 10 backcross-derived entries evaluated at Bajo.

Table 62 Details of parents and resistance percentage in the 10 entries.

Code	Name/Pedigree	Type	Remarks	Resistance
1	ShaEma/CriollodeMorelos334//ShaEma	Cayenne	G-R,6x1.5CM	PC(4%)
2	ShaEma/CriollodeMorelos334//ShaEma	Cayenne	G-R,6x1.5CM	PC(4%)

3	ShaEma/CriollodeMorelos334//ShaEma	Cayenne	G-R,6x1.5CM	PC(4%)
4	ShaEma/CriollodeMorelos334//ShaEma	Cayenne	G-R,6x1.5CM	PC(4%)
5	ShaEma/CriollodeMorelos334//ShaEma	Cayenne	G-R,10x1CM	PC(17%)
6	ShaEma/CriollodeMorelos334//ShaEma	Cayenne	G-R,10x1CM Early, Nice	PC(12%)
7	ShaEma/PI201234//ShaEma	Cayenne	G-R,8x1.5CM	PC(2%)
8	PBC 714	Cayenne	G-R,10x1CM	PC(25%)
9	PBC 390	Cayenne	G-R,8x1CM	Susceptible
10	PBC 950	Cayenne	Early, fleshy conical fruits	Local check

Table 63 **Data on Yield and other phenotypic traits.**

Entry	Treatment	Plot	Days to Anthesis (DAT)	Days to Maturity (DAT)	1=OK 9=Not OK Fruit Type (1-9)	10 Fruit Average Fruit length (cm)	10 Fruit Average Fruit Width (cm)	5 Plant Average Fresh Biomass (g)	10 Plant/plot Total Fruit Yield (kg)	1= Low 9= High *P. capsici* Score (1-9)	Others Remarks
P1	I	1	42	58	8	4.17	1.41	24.05	0.844	5	
P2	I	2	42	54	7	5.07	1.39	23.54	0.479	6	
P3	I	3	26	55	9	4.71	1.45	22.51	0.351	7	
P4	I	4	26	53	8	5.41	1.45	21.54	0.477	6	
P5	I	5	26	60	8	9.49	0.96	30.80	0.403	6	
P6	I	6	26	50	8	6.44	1.26	14.94	0.599	8	
P7	I	7	23	46	7	9.1	1.43	16.32	0.406	5	
P8	I	8	23	51	7	10.54	1.98	52.91	0.943	3	
P9	I	9	26	55	8	12.02	0.91	34.28	0.530	8	
P10	I	10	23	59	8	5.45	2.06	37.12	0.808	8	
P1	II	11	21	60	8	4.12	1.55	72.96	1.478	4	
P2	II	12	21	61	7	5.34	1.53	93.18	1.430	3	
P3	II	13	22	57	9	4.42	1.53	102.94	1.940	3	
P4	II	14	22	52	8	5.31	1.55	93.64	1.985	2	
P5	II	15	22	50	8	9.25	1.16	98.30	1.385	3	
P6	II	16	23	50	8	6.54	1.68	66.44	2.935	4	
P7	II	17	22	54	7	10.3	1.54	73.46	1.877	4	
P8	II	18	22	50	7	8.28	1.88	96.40	3.092	2	
P9	II	19	22	52	8	12.81	0.8	82.00	2.243	6	
P10	II	20	22	51	8	6.36	2.22	53.34	1.395	8	

Note: Fresh fruit yield was recorded weekly on data sheet, and the total recorded here after the final harvest.
DAT= Days after transplanting.
Treatment I = traditional practice, and
Treatment II = recommended practice.

No lines were selected because the fruit type, and other fruit characters were not acceptable to the local consumers.

5.2.2 Potato Disease Management using Farmer Field School

Potato is one of the most widely grown cash crops in Bhutan. It is grown in about 5654 ha in the temperate areas of Bhutan. The yields range from 15-25 t/ ha. There are more potential for increasing yield if proper disease management techniques are followed and better varieties identified. Although integrated control measures are available for the major diseases, they need to be further fine-tuned. A new approach that is commonly and successfully used in the rest of South East Asia called the Farmer Field School (FFS) is being tried with three potato growers of Phobjikha. This approach involves and educates the farmers through out the crop production process. It not only deals with the particular disease, but also gives emphasis on general crop sanitation techniques that will help minimize other problems as well.

The short-term objective of FFS is to effectively guide the farmers' to discover and induce implementation of the best available IPM packages and to minimize the incidence of disease and insect pests in potato. The long term objective is to help sharpen farmers' skills in the areas of observation on insects, disease symptom identification and decision making and also to help develop their power of critical thinking thus making it sustainable to improve their income and living standards.

Seeds of potato variety *Desiree* were planted on 23rd March 1999 on 50m^2/treatment plots using the standard practice for potato production at Moel, Tabading and Damchulakha villages under Phobji Geog (Figure 7). Three farmers were selected (one per village) and each farmer was taken as a replicate.

Figure 7 Farmers selecting and sowing seed potato.

The recommended LB control measures available were the use of fungicide Mancozeb or Copper Oxychloride before infection during conducive weather, or when the disease is in its early development stage, rouging of volunteer plants at the time of earthing-up and following proper plant spacing and timing (
Figure **8** &
Figure 9). Crop rotation (1-2 year) using alternate crops such as legumes, cereals and brassicas (but no solanaceous crop) was also included as a treatment. Improved drains were made in wet soil conditions favoring soil and tuber borne diseases. The crop was irrigated using the furrow system as and when needed. Data were recorded for the incidence of disease and insect pests and the yield. The objectives and goals of the integrated pest management using farmer field school and its implementation procedures (Table 64) were explained to the selected farmers and others from the three selected villages mentioned above. Hands-on training on agro-ecosystem analysis to sharpen farmers skills in the areas of observation on insects, disease symptom identifications and decision making were facilitated. Special topic issues on seed selection, rouging of volunteer plants and blight control methods were also facilitated and discussed during the cropping season.

Figure 8 Extension Agents demonstrating how to hill up potatoes appropriately.

Figure 9 Farmer practising appropriate hilling-up technology

Table 64. Implementation Plan for IPM using FFS

SESSIONS/TIME		ACTIVITY	GOALS	TOOLS
1-2	7-15 DBP	Explain good quality seed, about diseases (LB, soil and tuber borne diseases) and Production technology for potato.	Farmer will be able to select good quality seed and use proper production technologies	Framers meeting Practical demo. On production technique.
3	Planting	Fertilisation, spacing, seed size and seed treatment.	Farmer will learn appropriate fertiliser usage, spacing, proper seed size selection for planting.	Practical demo.
4	Before emergence (On need base)	Drainage, crust breaking, volunteer rouging.	Farmer learns how to rogue, break crust and improve drainage systems	Field demonstration by farmers in their own plots
5	Earthing-up	Size of hilling, N- top dressing, about late blight, roguing, fungicides use, variety and weeding.	Farmer will learn about appropriate hilling and N top dress. Also learn to identify LB Symptoms and apply appro.control measures	Meeting, practical Field observation on disease symp. identification.
6	Flowering stage	Control for late blight.	Farmer learns to recognize LB symptoms and take appropriate control measures	Meeting + field visits to infected areas & field observn. on study plot.
7	After flowering	Late blight control measures.	Farmer learns more about LB symptoms and appropriate controls.	Field visit (infected area) Field observn. On study plots.
8	Harvesting	Control for tuber and soil borne diseases plus post-harvest diseases and storage methods.	Farmer learns about soil and tuber diseases and the importance of storage methods. Also Learns how to treat the seeds.	Meeting, demo. on how to treat seeds Observn. of tubers.
9	Data Analysis	Interpretation of the data/ results, develop plans for the next season.	Farmer learns how to evaluate and make decisions for the next season	Farmers feedback Farmer planning meeting

As shown in Table 65, there is a significant difference in yield between treatment 1 and treatments 2 & 3 but there was no difference in yield between treatment 2 and treatment 3. The result shows that using good quality seed in combination with the recommended (late blight + cultural) practice of potato production tends to give higher yield than the farmers' practice. In all the treatments there were no incidence of diseases and insect problem during the cropping season this year. On a scale of 1-9 (CIP scale) the scores were 1 in all the treatments at 60, 70, 80, 90 DAP indicating no blight symptoms. In treatment 4 (crop rotation) no potato was planted this year but was used for growing leafy vegetables and turnips.

Table 65. Potato IDM Treatments and their total yield 1998-99.

Treatment	Total Yield (t/ha)
T_1 (Good quality seed + Recommended LB control measures)	33.5
T_2 (Farmers seed + Recommended LB control measures)	24.1
T_3 (Farmer seed + Farmer practices for LB control)	23.2
T_4 (Crop Rotation)	00.0
LSD at 0.05	9.20
CV %	15.1

Integrated pest management using the farmer field school approach was designed for 25 participants so that when completed these 25 farmers can constitute a neighborhood support group for IPM of a reasonable size within the context of a village. This was not possible in Phobjikha because of the scattered village location and distance between the villages. In the next potato season we hope to involve more farmers so that ultimately the idea of creating a neighborhood IPM support group is realized.

5.2.3 *Potamogeton distinctus*: a brief literature review

Potamogeton distinctus (Shochum) is a noxious perennial aquatic weed infesting wet land rice fields. It is a seed plant having true roots, stems and leaves. The abundance and the density of this weed are primarily dependent on the depth and turbidity of the water and the physical characteristics of the soil. It is a difficult weed to control by hand weeding since it is propagated vegetatively.

Chris Parker (1991) confirmed the species of *Potamogeton* occurring in Bhutan as *Potamogeton distinctus* A. Bennett during his visit to Bhutan as a weed consultant with National Plant Protection Centre, Ministry of Agriculture. Domingo C. Navarez who also visited Bhutan (through the Bhutan-IRRI wetland project) as a weed consultant found out that *Potamogeton sp.* found in Bhutanese rice fields was the same species as that occurring in Japan and Korea on which a number of studies have been published. Wiegleb, G. (1990) reports that the main difference from closely related *P. nodosus* is that the number of mature carpels is 1-3 rather than 4. He also implies that this character may not be sufficient reason for it being regarded as a distinct species, and that it could be treated as a subspecies of *P. nodosus* too.

Although *P. distinctus* produces plenty of seed which are presumably viable, it is the overwintering rhizome tips or 'turions' which are almost certainly the most important propogules, which can establish very rapidly once the rice is planted. Among the papers on the biology of *P. distinctus,* Kim and Jae (1977) reports that this species requires 30 cycles of short day for transformation of the actively growing rhizome tip into the 'turion' by which it overwinters. In Korea, this occurs in mid-September (Kim, Heu and Bae, 1976). One report from Japan (Wiegleb and Kadono, 1989) records that no turions were formed when there was rapid drying out of the site at the end of the season. Lee, Park and Lee (1976) reports that turion formation can be prevented by 2 hand-weedings, one 17 days after transplanting, and other 'at flowering' (not clearly stated whether its of rice or weed). Two papers (Kim and Choi, 1976; and Lee, Park and lee, 1976) record that the turions are mostly between 10 and 20cm deep in the soil.

Sprouting of the turions apparently requires that they first be partially dried out. Takayama and Suge (1984) found that if they had not been dried down to 30-50% of their initial weight they would not sprout in wet soil even after 6 months. Further drying is less damaging to *P. distinctus* than to other perennial rice weeds, and even a further reduction to 40% of their over-winter weight causes only partial loss of viability. However, turions left on the surface of dry soil were dead within a few days (Kasanagi and Chang, 1979). They are not damaged by temperatures down to -5^0C (Kasanagi and Chang, 1976) and at least 50% can emerge from burial to 15cm soil depth.

Flooded conditions are essential for natural sprouting (Kim and Jae, 1977). Optimum temperatures are 15-22^{0}C (Pyon, Kang, Park and Kang) and a temperature of 30^{0}C greatly suppresses sprouting. Kim, Heu and Park (1977) also recorded that *P.distinctus* is very susceptible to high temperature, being killed in one hour at 45^{0}C, but this refers probably to the growing plant rather than to the turions. Detailed work by Suge (1975) showed that a build up of both ethylene and carbon dioxide (C_2H_4

and CO_2 respectively) in the soil are important in the natural sprouting process. This build-up can only occur under saturated conditions.

Yield reductions reported vary from 43% (Kim, Heu and Park, 1977) and 57% (Kim, Heu, Park and Jae, 1977) using very high artificial populations, to 16%, presumably with a natural population (Lee, Park and Lee, 1976).

Among control measures, Kim and Choi (1976) reports 64% reduction by autumn ploughing to 20cm. Successful chemical control is reported by 'Avirosan' (4:1 piperophos + dimethametryn) at 30kg granules per hectare (Lee, Park and Lee, 1976) and by 'Avirosan' 10 days after transplanting (DAT) followed by 2,4-D (Kim, Heu and Chang, 1975). Yang, Park, Chung and Kwon (1980) also reported excellent control by 'Saturn S' (thiobencarb plus simetryne).

5.2.4 *Potamogeton distinctus*: a review of the past research in Bhutan

Potamogeton distinctus (locally known as 'Shochum') has in the recent past become a major dominant weed of rice in several important rice-growing districts of Bhutan. It is abundantly found in flooded conditions at middle altitudes of 1200-2500 m. The severity of 'Shochum' weed appears to be increasing in the Punakha-Wangdue valley rice growing areas. This has happened mainly because of the use of 'Butachlor' in transplanted rice which eliminates almost all the grasses and sedges that otherwise competes with 'Shochum' for nutrients, sunlight, space etc., and the use of 'Urea' (fertiliser) top dressing technology in rice that the farmers of these valley have adopted which enhances the growth and propagation of 'Shochum'.

Traditional methods of hand weeding of 'Shochum' are labour intensive and relatively ineffective. Chemical herbicides like SANBIRD and NC 311 were proven to be effective but are very expensive and environment unfriendly in longer run. Therefore, to know what needs to be done for the control of 'Shochum' a review of the past research was done.

Various pre-emergence herbicides like Sanbird (pyrazolate), NC311 (pyrazosulfuron-ethyl), Londax (bensulfuron), Avirosan (4:1 piperophos + dimethametryn), Mamet sm and Punch (Butachlor) in comparison with 2 Hand weeding and 2 Rotary weeding at 20, 35DAT respectively were studied for their effectiveness against 'Shochum' weed at Lobeysa, 1400 masl (Annual Report: Centre for Agriculture Research and Development, Bajo, 1988). It was reported that plots treated with Sanbird, NC311 and Londax yielded significantly more grain than the hand weeded and unweeded check. NC311 treated plots had a yield increase of 1.67 t/ha (33%) compared to hand weeded plots and an increase of 1.47 t/ha (28%) when compared rotary weeded plots. The study also found that the lowest grain yield was from Butachlor treated plots which yielded significantly less than the hand weeded ones indicating the ineffectiveness of herbicide Butachlor in controlling *Potamogeton distinctus* weed.

In 1989 advanced evaluation trials using pre-emergence granular herbicides were conducted both on-farm (Paro, Punakha and Wangdue valley) and on-station at Bajo, Wangduephodrang. The herbicides were NC311, Londax, Sanbird, Herbit, Grakil (phenothiol and symetryn), Mogeton in comparison with the farmer's practice

of hand weeding. In the advanced evaluation trials conducted in Punakha-Wangdue valley it was reported that plots treated with Londax, NC311, and Sanbird yielded higher grains than the hand weeded plots (farmer's practice). Sanbird was found to be the only herbicide that yielded significantly more grains than the farmer's practice of hand weeding. Herbit was reported to be phytotoxic and the plots treated with Herbit yielded less than the hand weeded ones. In another advanced evaluation of herbicides against 'Shochum' conducted in the valley of Paro it was reported that there was no significant difference between treatments in their effect on the grain yield. Plots treated with Herbit had significantly more 'Shochum' weed present compared to the other treatments that did not differ from each other.

In the trial conducted at Yusakha at Lobesa it was found that the use of Londax, Sanbird, Grakil, Mogeton, Avirosan, NC311, Rotary weeding and Hand weeding were significantly higher in controlling 'Shochum' when compared with the weed weights from the unweeded check. The yield of the plots treated with the above mentioned herbicides were found to be at least 1.64 t/ha (24.4%) higher than the unweeded check. Weed weights recorded in the Herbit treated plots were found to be non-significant when compared with the unweeded check and Herbit was reported not controlling 'Shochum' (CARD Annual Report, 1989).

In an experiment to study the effectiveness of selected herbicides against *Potamogeton distinctus* weed both on-station and on-farm (Lobeysa) it was reported (CARD Annual Report, 1990) that plots treated with Sanbird and NC311 gave significantly higher yield compared to the farmer's practice of hand weeding. The highest yield was obtained from Sanbird treated plots and was reported to be significantly higher than NC311 treated plot yields. It was also reported that the Sanbird treated plots gave significantly higher straw yields (taller plant height and more number of panicles per hill) when compared with the other treatments. In Herbit treated plots the straw yield, plant height and number of panicles per hill were reported as not significantly different to that of the unweeded check. The following recommendations were made on the use of Sanbird, NC311, Herbit and Rotary weeding:

- Sanbird was recommended for use in areas predominated by 'Shochum' complexed by the presence of other weeds as it was found to be effective against all types of transplanted rice weeds.
- NC311 was recommended for use against 'Shochum' and a few selected sedge and grass weeds of rice.
- Rotary weeding in paddy fields where line transplanting is done to control 'Shochum' and other weeds.
- Herbit was not recommended for use against both 'Shochum' and other rice weeds.

In a study conducted on-station to determine the critical period of rice-'Shochum' competition it was reported that allowing the rice crop to compete with 'Shochum' for more than three weeks reduced rice yields (CARD Annual Report, 1990). It also reports that 'Shochum' sprouts as early as the first week after transplanting and that the fresh weight of 'Shochum' increased significantly after third week of transplanting indicating increase in biomass and becoming more competent. The result of the study was cautioned by the scientist involved saying that it was the outcome of interplay of many factors like aged seedlings of rice (60 days old), lack of irrigation water and delayed planting which attributed to low yield.

In 1991 a study was conducted to determine the efficacy of Sanbird and NC311 herbicides at application rates lower than those recommended by the manufacturing companies. The application rates used were 0.020, 0.015, 0.010 kg a.i./ha for NC311 and 3.50, 2.50, and 1.50 kg a.i./ha for Sanbird respectively in comparison with hand weeding at 20 and 40 days after transplanting (DAT). Statistical analysis reported (CARD Annual Report, 1991) no significant differences in yield among the treatments. However, significantly lower weed weights were reported as compared to the farmer's hand weeded treatment. NC311 was reported to be ineffective at lower rates than the recommended rate.

In 1992 a long term trial was conducted to study the effect of Sanbird and NC311 as very little information exists regarding continuous use of these herbicides on the growth and biology of 'Shochum' (*Potamogeton distinctus*) weed in transplanted rice. The treatments were Sanbird @ 3.50kg a.i./ha, Sanbird @ 3.50 kg a.i./ha + 1 Hand weeding at 30 DAT, NC311@ 0.020kg a.i./ha, NC311@ 0.020 kg a.i./ha + 1 Hand weeding at 30 DAT, 4 Hand weedings at 2,4,6,8 weeks after transplanting (WAT), and unweeded check. Significant differences in yield and weed biomass were reported among the treatments. The unweeded control plots had the highest weed weight (significant from the treated at P=0.05) leading to significant yield decline. Weed biomass reduced significantly in the treatment where Sanbird alone was applied, which was statistically comparable to four hand weedings. It was reported that additional hand weeding with NC311 also decreased weed weights significantly. Sanbird was reported to be the more effective than NC311. Yield loss due to weed competition was estimated to be 43% from the highest yield obtained during this experiment. It also reported that compared to hand weeding 27% of the yield was lost due to weeds.

5.3 Water Management Research

Introduction

The Water Management Research (WMR) originated from the need felt within the Ministry of Agriculture for a sustained national research effort to study the relations between water management practices, soils and crop production. In the broader context, WMR has the following objectives:

- to raise the productivity of existing rice-based irrigation schemes through durable improvements in water delivery
- to increase rural incomes by diversifying the range of irrigated crops on wetland as well as on dry land
- to rationalise the irrigation assistance programme with a view to increase the role of water users and the private sector, and to reduce recurrent government investments in irrigation scheme.

Within these objectives the mandate of the WMR is to assess the performance of alternative irrigation systems and water management practices for a range of food and alternative crops, with the view to increase the returns to land and labour on a sustainable basis. To do so the WMR aims to initialise and institutionalise water management research within the national research program and to conduct trials and studies on water management and appropriate irrigation technology both at farmers' fields and on-station. The WMR has its base at RNRRC Bajo, where it forms an integrated part of the overall research program.

5.3.3 Improved water management in rice

The farmers' practice of paddy cultivation uses more water than is required. High water level at transplanting followed by deep standing water maintained in the terraces almost throughout the growing period result in low water use efficiency (WUE). The high water demand exerts pressure on the scarce water resource. To aggravate the situation, the peak rainfall and peak transplanting seasons are out of phase by a month. The mountain climate does not allow the shifting of the transplanting period to match the rainfall pattern.

Farmers report certain points favouring the present practice, like weeds suppression and insurance against unreliable water supply. But water shortage has become the main and pressing issue which justifies a research intervention. Two studies on improved water management for rice done in Bihar and Gujarat have generated encouraging results. The study in Bihar gave a yield improvement of 34% over the farmers' practice and significant increase in water use efficiency. The Gujarat study showed 29% water saving and 55% higher yield per unit of water applied by adopting improved water management practices. The average yield increase in the study plot was 10.3% more than the control plot. The general indication from the studies is that rice crop does not require continuous flooding at the usual high water depths maintained by the farmers. Improved rice varieties with improved water management practices can substantially increase yield as well as WUE on farms with irrigation.

The main objectives of this research were to compare the water use efficiency between the traditional and the improved methods in terms of yield and the management requirement. If the same yields could be harvested with less water, water shortage problem would be addressed to a certain degree.

The following materials were used in the research:

(i) Wooden pegs with alternate rings of red and yellow ;
(ii) WBC flume to measure quantity of irrigation water;
(iii) Plastic rain gauge to measure rainfall;
(iv) Stop watch, and
(v) Weighing balance

The research was done on-station. There were two replications, each comprising of three plots with three different treatments. Treatment 2 was given 5 cm depth of water with one day stress period, Treatment 3 was given 7 cm depth of water with three days stress period, and Treatment 3 was the control reflecting the farmers' practice. The water depth in Treatment 3 was always maintained at 5-10 cm. The replications were adjacent to each other to ensure similarity in all aspects. The water level in the plots was monitored with the use of wooden pegs with alternate rings of red and yellow. Each plot had 10 uniformly spread pegs. The stress period was counted when the soil under 8 of the 10 pegs had no standing water. The next irrigation in Treatments 2and 3 was given after 1 day and 3 days' stress period, respectively. The control was irrigated whenever the water level dropped to approximately 5 cm.

The flow into the plots was measured with WBC flume and the depth of water to be applied was determined with the rings of the pegs. The plot size was approximately 18.35 m x 7.35 m (1998) and 7.10 m x 3.20 (1999). The total quantity of water given to all plots from transplanting to maturity was recorded. The quantity of water given at each irrigation was determined as the product of discharge and the time taken to fill up the required depth.

Three crop cut samples from each plot were assessed for yield. The weeds from all plots were collected and their dry weights recorded. All other management practices such as application of weedicides (butachlor) and fertilisers were the same in all the plots.

The total quantity of water applied in Treatment 1 was the highest (729 mm - 1998) while that in Treatment 3 was the least (477 mm) with a rainfall of 454 mm for both Figure 10The farmers' practice used 27% more water than Treatment 2 & 3. While there was a significant difference in the water used between the treatments, the yield difference was not significant (Figure 11). As a result there was an increase in water use efficiency of 29% between Treatments 1 and 3 (Figure 11). From this it can be inferred that paddy can be cultivated using less water compared to the traditional practice; for every three hectares, one more hectare could be cultivated with the same quantity of water.

Figure 10 Total quantity of water used for rice production 1998/99

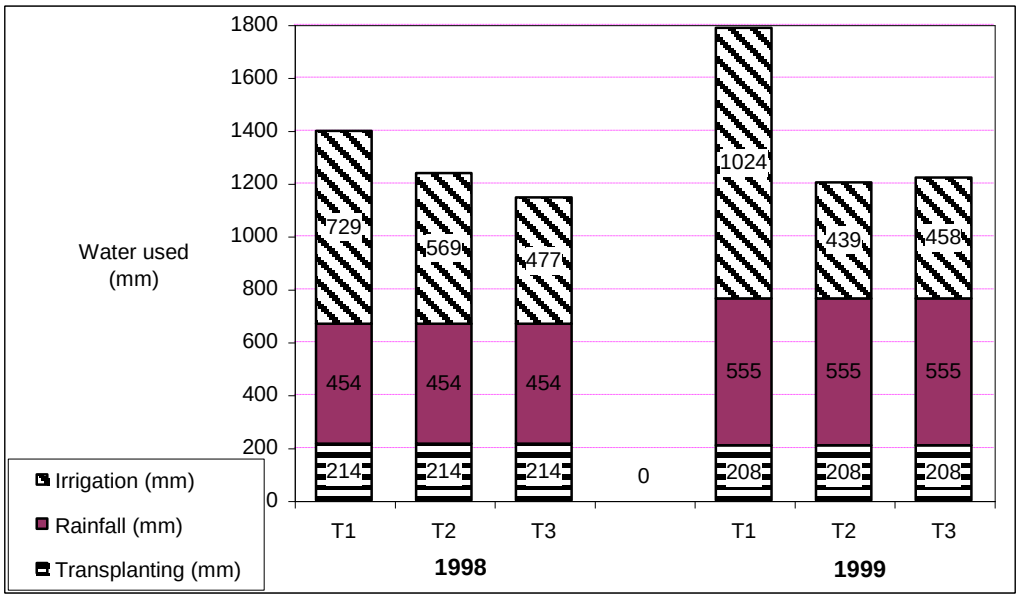


Figure 11 Rice Yield for 1998/99

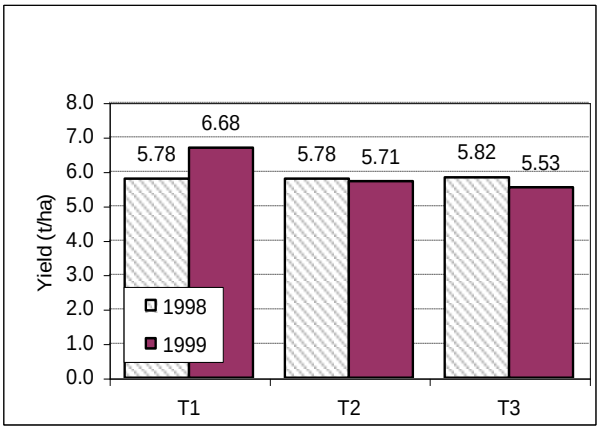


Figure 12 Quantity of water used to produce a kilogram of rice

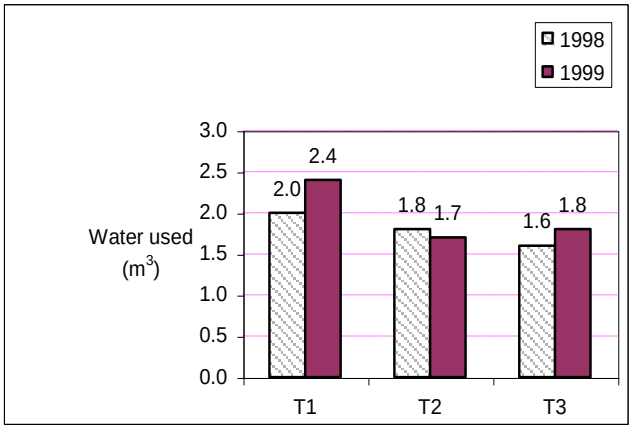
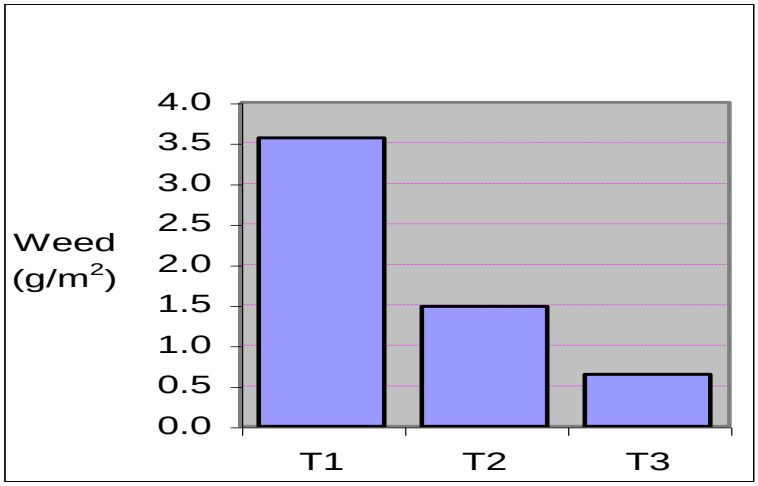


Figure 13 Dry weight of weeds (1998 data only)



The farmers' practice (Treatment 1) recorded the highest dry weight of weeds of 3.56 g/m^2 (Figure 13) while from Treatment 3 the dry weight recorded was 0.64 g/m^2. These results disapprove the farmers' notion of weed suppression by high depth of standing water. Standing water suppresses only non-aquatic weeds while aquatic weeds proliferate in more water. Major portion of the weeds in Treatment 1 was a aquatic weed (M*onochoria vaginalis*) as a result of keeping standing water continuously.

Treatment 1 required 12 irrigations at an interval of seven days, Treatments 2 and 3 were irrigated only four to five times at an interval of 17 days each (Table 66). This implies that the improved method requires less labour days for irrigation than the farmers' practice.

Table 66 Summary of the results of 1998 and 1999

Treatments	Yield (t/ha)		No. of irrigation		Transplant-ing		Rainfall (mm)		Irrigation (mm)		Total water used (mm)		Water used (m^3/kg rice produced)	
	'98	'99	'98	'99	'98	'99	'98	'99	'98	'99	'98	'99	'98	'99
T1	5.78	6.68	12	12	214	208	454	555	729	1024	1397	1787	2.0	2.4
T2	5.78	5.71	5	4	214	208	454	555	569	439	1237	1202	1.8	1.7
T3	5.82	5.53	5	4	217	208	454	555	477	458	1145	1221	1.6	1.8

There is no significant yield difference between the improved method and farmers' practice while there is a significant improvement in water use efficiency of 29 % with the improved method. With the adoption of the improved water management practices, there is no additional management requirement. If the improved management practice is adopted, the water shortage problem will be reduced if not solved.

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Appendix 1 : International Rice Hybrid Observation Nursery (IRHON)

Designation	VG (1-5)	50% FLW (d)	Pht. (cm)	PaCp (1-5)	Panicle No./hill	Yield (t/ha)
IR 62030-54-1-2-2R	3	103	93	1	11	7.78
IR 62037-93-1-3-1-1R	3	101	80	3	12	4.54
IR 64616H	3	109	85	3	10	6.56
IR 62917-20-3-3-1-1-2R	3	100	90	3	-	5.98
IR 5514-5-3-3-3R	3	115	84	1	-	4.97
IR 73409H	3	113	83	3	9	9.00
IR 70	3	103	77	3	12	6.80
IR 62030-83-1-3-2R	3	101	88	3	-	6.12
IR 73864H	3	102	88	1	-	7.80
IR 73884H	3	122	83	3	11	4.24
IR 67693H	3	113	90	3	11	7.57
PSB RC-2	3	128	78	5	9	4.40
I 23352-7R	3	104	84	1	-	4.45
IR 48725-B-B-38-1R	3	103	113	3	10	4.58
IR 71100H	3	112	93	1	12	7.70
IR 73872H	3	105	88	3	11	8.55
TAI YOU SONG	3	113	92	1	9	3.64
IR 73856H	3	101	84	1	9	7.51
IR 71097H	3	105	83	3	10	7.61
IR 73865H	3	101	80	3	11	8.07
IR 56381-139-2-2R	3	100	84	1	-	7.06
IR 64616H	3	105	86	3	10	5.58
IR 72071H	3	113	89	5	9	5.93
IR 64	3	122	89	1	12	6.40
IR 65515-47-2-1-1-9R	3	139	100	1	9	6.18
IR 67693H	3	109	85	3	11	8.12
IR 73403H	3	103	83	3	8	8.16
IR 73858H	3	101	92	3	9	7.19
IR 73411H	3	105	86	3	9	5.45
IR 72	3	129	73	3	10	7.42
IR 73863H	3	101	87	1	-	7.90
IR 56450-4-2-2R	3	109	91	1	13	7.75
IR 73408H	3	112	109	1	10	8.14
IR 71097H	3	105	92	3	9	8.38
IR 60821-34-1-2R	3	122	88	1	-	6.00
IR 73855H	3	103	86	5	8	7.90
IR 43342-10-1-1-3-3R	3	139	92	1	-	6.78
IR 71100	3	110	94	3	13	8.18
IR 59624-34-2-2R	3	98	76	3	-	5.32
IR 73875H	3	111	84	3	10	7.96
IR 62917-97-2-2-2-3R	3	104	84	3	9	6.86
IR 60997-16-2-3-2-2R	3	122	84	5	10	7.67
IR 71097H	3	104	84	3	10	8.07
IR 73869H	3	104	92	3	9	7.88
IR 68888B	3	98	75	3	-	4.97
IR 62930-17-2-1-3-2R	3	98	72	5	10	4.89
IR 67693H	3	111	85	3	13	6.60
IR 58082-126-1-2R	3	98	65	3	15	3.59
IR 62036-222-3-3-1-2R	3	104	83	3	10	6.98
IR 73880H	3	122	104	3	11	8.65
IR 71100H	3	109	94	1	13	8.49

PR 22896-225R	3	122	101	3	8	6.59
IR 68897B	3	101	80	3	-	8.27
IR 71102H	3	102	109	1	10	8.27
IR 64616H	3	113	84	3	12	6.91
IR 63881-49-2-1-3-2R	3	122	91	3	11	6.80
IR 60913-42-3-3-2-2R	3	128	84	3	-	6.27
IR 29723-143-3-2-1R	3	140	92	5	-	8.57
IR 72	3	122	84	5	-	5.09
IR 68886B	3	122	94	5	12	7.36
IR 55838-B2-2-3-2-3R	3	142	88	5	-	4.78
IR67693H	3	113	89	3	17	7.16
SHANYU 878	3	113	106	1	11	7.60
IR 73412H	3	128	101	3	-	4.22
IR 65514-96-1-1-3R	3	139	103	3	-	1.25
IR 71097H	3	105	88	1	11	8.6
IR 61614-38-19-3-2R	3	113	83	3	8	7.18
IR 69628B	3	113	94	3	13	8.86
IR 58025B	3	122	87	3	10	5.20
IR 64616H	3	106	81	3	13	4.34
IR 71088H	3	123	92	3	-	5.45
IR 63883-41-3-2-2-2R	3	128	87	5	-	3.76
IR 73859H	3	98	85	3	10	4.98
IR 71100H	3	105	90	1	12	7.19
IR 72832H	3	100	92	3	10	8.20
IR 62829B	3	104	81	5	11	6.58
IR 73850H	3	101	82	3	10	6.54
IR 72	3	112	83	5	11	6.72
IR 68885B	3	104	76	5	13	6.27
IR63870-123-2-2-2-2R	3	112	79	5	11	7.20
PMS10B	3	128	76	3	-	4.34
IR 62171-122-3-2-3-3R	3	111	85	5	13	7.56
IR 67693H	3	113	93	3	11	6.20
IR 73862H	3	181	92	3	8	6.80
IR 69627B	3	100	85	3	-	5.32
IR 42	3	142	87	5	-	2.83
IR 64616H	3	113	83	3	14	6.86
IR 71092H	3	122	93	3	9	5.53
IR 73877H	3	142	91	5	-	1.63
IR 50	3	104	77	3	14	4.48
IR 71097H	3	105	93	3	10	7.08
IR 71101H	3	99	86	3	-	7.24
IR 71115H	3	128	104	5	-	3.40
IR 44962-7-6-2-2R	3	122	92	5	-	4.91
IR 72	3	113	85	5	11	6.52
IR 72074H	3	122	94	1	-	-
IR 73402H	3	100	87	1	14	6.73
IR 73857H	3	101	91	1	11	7.54
IR 71100H	3	109	86	1	10	7.89
IR 73401H	3	105	98	1	7	7.02

Appendix 2 : International Rice Blast Nursery (IRBN)

Designation	Leaf blast (0-9)	Panicle blast (0-9)
IR 1552	0	1
IR 64	0	1
B 40	0	9
ZECHUM	0	9
AMAROO	0	9
APURA	0	0
ARC5780	4	0
B2983B-SR-85-3-2-4	0	0
B3016B-TB-260-3-2-1-1-3	0	0
B4350H-MR-24-3-2-1	3	0
B6414F-TB-1	4	0
B6805E-TB-2	0	1
B6806E-TB-1	0	1
B6831F-TB-1	1	0
B7291D-SM-12	1	0
BR1244-9-1-2-1	1	0
BR14	0	0
BR1668-11-3-3	1	0
BR1725-13-7-16	4	7
BR2899-108-1-1-4	2	0
BR4701—2-6-5	1	0
BR4726-2B-6-1-3	0	0
BR4839-26-5-5-2	1	0
BR4839-26-7-1-5	1	0
BR4839-28-1-5-2	4	0
BR5129-17-5-4	3	0
C1954-242	4	0
CEYSVONI	2	0
CNA3891	1	0
CNA6710	0	0
CNA6870	1	0
CNA7024	0	1
CNA7227	1	0
CNTBR82074-210-1-2-1	1	0
CT6196-33-10	1	0
CT6946-9-1-2-M-1P	0	1
CT6947-1-1-1-7	1	0
CT7242-16-3-3-3-2P	0	0
CT8249-2-7-2-M-1P	1	0
CT8402-6-M-2-1-1-M	0	1
DENALO	0	5
F14-3	1	0
F21-6	0	0
F25-3	0	1
F40-3	1	1
F59-1	1	1
F66-10	1	1
FARO-40	0	0
FKR-33	0	1
FKR-27	0	0
IR 1552	0	0
IR 64	0	0
B40	-	9
ZECHUM	-	9

HEXI-10	1	0
HEXI-15	0	0
HEXI-2	1	0
HEXI-22	0	0
HEXI-24	0	1
HEXI-25	1	1
HEXI-30	0	1
HEXI-4	0	1
HEXI-5	0	0
HR4856-1-1-1-1-2	0	0
HUANC CENC-1	0	0
IR 44530-41-1-2-1	0	0
IR 45517	0	1
IR51673-172-1-3	0	0
IR 52350-81-3-1-2	1	0
IR 53386-100-3-2-2	1	0
IR 53912-98-1-2-2	1	0
IR 54852-129-1-2-3-2	0	0
IR56450-28-2-2	0	0
IR 57298-31-2-2	0	0
IR 57893-08	0	0
IR 57932-06	0	0
IRAT 170	0	0
ITA 323	1	0
JAVAE	1	0
LEBONNET	0	0
MTU 9991	2	0
MTU 2077	2	-
NABATAT ASMAR	0	0
NAN QING AI	2	0
NEWREX	0	0
NONG HU 6	0	3
NOVA	0	1
OM269-65	0	0
PERFR84001-17-B	1	-
QI LONG 1	-	7
QUING LIU AI NO1	1	0
REPL 3-2	1	0
RIL 13	1	0
RIL 23	1	5
RIL 276	1	7
RIL 38	1	7
RP2095-5-8-31	0	0
RP2167-323-1-2	1	0
S. ANDREA	0	7
SAN WANG ZHAN2	1	0
IR 1552	0	0
IR 64	1	0
B40	-	7
ZECHUM	-	7
SHENSHOU IBARAKI 1	7	7
SHUAN HUA AI	1	0
SIN EKARI 1	0	0
SR 10255-B-57-3-2	1	0
SR13363-28-2-1	1	0
STARBONNET	1	1
TAISEN YU 255	1	0
TOX 1011-4-AZ	-	1

TOX 1889-22-101-1	1	0
TOX 1889-7-105-2-1	1	0
TOX 3107-6-1-2-2	1	0
TOX 718-1-24	1	1
TOX 955-208-2-102	1	0
VANDANA	0	3
WAB181-18	0	0
WAB181-43	0	0
WAB 30-24	-	0
WAB 32-46	0	1
WAB 32-60	1	0
WAB 33-19	0	1
WAB 33-25	0	3
WAB 56-39	0	0
WB 56-57	0	0
WB 96-1-1	0	1
WAB 96-24	0	1
WAB 99-2-1	1	1
WABIS 18	1	0
WABIS 550	1	0
XIANGZI 3150	1	0
AICHI ASAHI	1	7
B2433B-KN-10-1-1-1	1	-
B21	1	1
C101A51	1	3
C101LAC	1	1
C101PKT	0	0
C105TTP-2LP	0	1
C22	1	1
CALORO	-	7
CHIANUNC	1	-
CHOKOTO	0	0
CO25	0	0
CO39	1	7
COLOMBIA 1	0	0
DINORADO	0	0
DULAR	1	3
FUJISAKA 5	0	3
IR 1552	0	0
IR 64	1	0
B40	8	7
ZECHUM	8	7
FUKUNISHIKI	0	0
IAC25	0	0
IR10011-16-3	1	1
IR14632-2-3	5	0
IR22082-41-2	1	0
IR32429-122-3-1-2	0	0
IR36	0	1
IR42	1	0
IR50	1	0
IR64	5	0
IR74	7	0
IRAT104	1	0
IRAT13	0	0
IRAT144	0	0
IRI317	1	0
IRI387	1	1

ISHIKARI-SHIROKE	0	3
ITA212	1	0
K2	0	5
K60	0	1
KANTO 51	0	3
LI-JIANG-XIN	1	7
MILYANG 82	0	0
NP125	-0	7
PAI-KAN-TAO	0	1
PETA	1	0
RAMINAD STR 3	1	0
RAU4004-127	1	0
SHIN 2	0	0
TA-POO-CHO-Z	0	0
TADUKAN	1	0
TAICHUNG T.C.W.C	0	3
TETEP	0	0
TSUYUAKE	0	0
USEN	0	1
ZENITH	1	1
IR1552	1	1
IR64	0	0
B40	-	-
ZECHUM	-	7

Appendix 3 : List of Local Rice Germplasm rejuvenated and characterized

Acc. No.	Variety	50% FLW (days)	Height (cm)
016	I-Zong	150	-
116	Thosar	150	-
117	Jirasari	-	-
118	Kartikay	150	-
119	Assamay	150	-
120	Duelhay marsi	150	-
121	Krishna Bhog	150	-
122	Bhotay Dhan	-	-
123	Jirasari	-	-
125	Pakhey Dhan	-	-
126	Marsi	-	-
160	Bincutee	122	-
162	Teng bar	-	-
164	Biscutee	-	-
170	Kateekay	150	-
171	Dalimay mashino	150	-
172	Khamte	142	-
174	Choti Masino	-	-
175	Bartshampa	118	143
176	Kemdep	115	120
177	Karma Tekpa	127	139
178	Negpa	118	140
179	Bapa Amshu	122	124
180	Shung Shung Bara	118	144
181	Kalu Malu	118	143
182	Khopthang salu	109	140
183	Mobzangmo Bra	122	135
184	Pasing Deb	115	141
185	Sonala	115	139
186	Khemdeb	116	137
187	Shung Shung Bara	127	115
188	Shangyepa	116	151
189	Karma Tekpa	127	150
190	Meypa	116	143
191	Chalangma	116	146
192	Khopthang salu	111	135
193	Shung Shung Bara	127	155
194	Bapa Bara	122	115
195	Dhakpa Bara	111	123
196	Chuphalopa	122	138
197	Gonbra	115	129
198	Karma Wangdi	136	143
199	Asu	86	96
200	Nera Bara	120	143
201	Zekha	115	94
202	Chadep	120	137
203	Zekha	115	103
204	Asu	-	-
205	Wangdue Karma	122	95
206	Zhungkha Bara	115	108
207	Padhang Salu	102	128
208	Shung Shung Bara	115	116
209	Baypo	127	129

210	Khopthangla	111	120
211	Pashing Deb	111	126
212	Phakpa Deb	111	148
213	Labshu	115	129
214	Pang Bra	111	131
215	Zubra	122	144
216	Bidungpa	122	135
217	Assu	127	110
218	Yengtshang bra	122	139
219	Desing Bra	115	82
220	Ngalong Bra	120	138
221	Hunda	115	116
222	Teakpu	122	148
223	Bumdilingpa	122	145
224	Tshang Napa	115	148
225	Asu balingmu	111	116
226	Tshalu Zubara	115	128
227	Tshalu assu	116	76
228	Shung Shung Ma	122	155
229	Mabra	115	149
230	Baypo	122	135
231	Prangpo Yartey	127	130
232	Shung Shung Bra	122	126
233	Kurtoezamo	118	143
234	Kambra pheza	116	136
235	Bulizamo	116	132
236	Kam Bra	116	148
237	Tshering Zamo	127	158
238	Wangdi Karmo	127	150
239	Golipang Bra	127	154
240	Pang bra Pliza	116	132
241	Wangdi Karma	116	151
242	Kurto Jammo	115	150
243	Jubara	115	148
244	Karang	122	136
245	Sung Sung Bara	116	157
246	Bomdilingpa	116	151
247	Wang Chu bara	102	138
248	Wangdi karmo	122	130
249	Pong Bara	122	128
250	Aasue	118	151
251	Ngalong Bar	116	126
252	Rang Shing Kharpa	118	139
253	Brana	116	121
254	Say Chum	111	-
255	Wang Karmo	133	-
256	Tsherang Zam	133	-
257	Tsherang Zam	133	-
258	Bara Dama	133	-
259	Chena Mo	127	-
260	Pang Bara	-	-
261	Rice White	-	-
262	Rashu Bara	122	143
263	Nam Nang Bara	116	115
264	Karma Wangda	127	162
265	Kham Nang Pa	116	111
266	Pang Bar	116	148
267	Brena	122	134

268	Sor Bang	116	159
269	Kham Dang Pa	116	157
270	Fo Bara	116	148
271	Sor Bang Barma Bara	96	152
272	Asu Salu	106	140
273	Zubara	116	152
274	Rashu Bara	122	161
275	Shung Shung Bara	127	157
276	Shung Bara	118	146
277	Nira Bara	133	140
278	Wangdi Karmo	127	138
279	Zhung Bara	124	-
280	Owling Bara	127	-
281	Shung Shung Bara	122	-
282	Pang Bara	116	-
283	Aaring Bara	116	-
284	Galing kharpa	127	-
285	Shung Shung Bara	122	-
286	Shung Shung Bara	118	-
287	Kalingpa	118	-
288	Catsalu	122	149
289	Khalingpa Bara	116	153
290	Aaring Bara	122	148
291	Brana	118	152
292	Aaring Bara	118	144
293	Masop	118	146
294	Aaring Bara	118	149
295	Aaring Bara	118	136
296	Sarbang bar	122	123
297	Pang Bar	102	115
298	Asu Bar	116	150
299	Wangdi Karmo	102	114
300	Tonglingpu	116	153
377	Shung Shung Bara	115	114
378	Sharpa Bara	-	-
379	Pang Bara	-	-
380	Mongar Bara	-	-
381	Ijung	115	105
382	Mongarpa	-	-
383	Wangdi Karma	-	-
384	Nagakhaly	-	-
385	Kolomeya	-	-
386	Tingrey	-	-

Appendix 4: Early tomato cost benefit analysis

Yield (mkt)	Price(Nu)	GR(Nu)				
448.36	30	13450.8				
Expenditure						
materials						
INPUTS	quantity	unit	price/unit	price		
seed	10	gm	2	20		
fym	800	kg	1	800		
mulch	40	kg	0.05	2		
chemical				0		
ssp	2000	gm	0.008	15		
suphala	2880	gm	0.0125	36		
aminos	100	ml	5	500		
copper sulphate	96	gm	0.048	4.608		
fym	36	gm	0.036	1.296		
other						
Total Inputs				**1378.90**		
Labour						
LABOUR	# persons	hours	rate	price		
install polytunnel						
pre irrigate soil	1	3	10			
trenching	3	3				
frame assembly	6	6				
plastic cover	6	3				
nursery prep						
seeding	2	4				
potting	1	1				
shift pots	1	2				
nursery main						
spray	1	1				
top dress	1	1				
land prep						
rotoring	1	1				
bed prep	3	3				
fym	2	3				
transplant						
third	2	3				
weeding	2	4				
crop care						
top dressing	2	6				

staking	2	2				
spray	1	3				
adjust polytunnel	1	3				
mulch	1	1				
irrigation						
nursery	1	30				
transplanting	1	20				
crop maintain	1	20				
harvest	3	30				
post harvest						
uproot	2	4				
plastic remove	2	2				
Total Labour		159	10	**1590**		
INVENTORY	year acquired	purchase price	life	annual dep	days used	price
land						
polytunnel						
plastic	1997	5000	3	1667	150	684.93
frame	1997	12000	5	2400	150	986.30
farm machines						
sprayer	1996	1300	10	130	3	1.07
power tiller	1996	90000	5	18000	1	49.32
rotovator	1996	25000	5	5000	1	13.70
plow	1996	15000	5	3000	1	8.22
hand tools						
spade	1997	250	3	83	4	0.91
hoe	1997	150	3	50	6	0.82
irrigation						
bucket	1997	200	3	67	5	0.91
hose	1998	500	4	125	40	13.70
water can	1999	200	3	67	106	19.36
other						
Total Inventory						**1,779.24**
Total costs	**4748.15**					
Gross Revenue	**13450.8**					
Cash Income	**8702.65**					

Appendix 5: Results of various products dried

Crop	Variety	Source	Date Start	Price fresh / kg	Price dry / kg	Price Dry + Drying Cost / kg	Weight Start kg	Weight Finish kg	Weight Loss kg	Finish %	Loss %	Metre Use kwh	Total Time hr	Power Cost	Cost / hr
Saag	dark green	wangdi	06/09/98	5.7	63.54	184.80	0.53	0.05	0.48	8.97	91.03	9.6	19.75	5.76	0.29
	chard	thimphu	15/09/98	20	190.94	253.90	1.0645	0.1115	0.95	10.47	89.53	11.7	34.5	7.02	0.20
	mgreen	thimphu	10/09/98		0.00	155.68	0.3445	0.0185	0.33	5.37	94.63	4.8	15.25	2.88	0.19
	mgreen	wangdi	15/11/98	5	67.06	132.47	1.8575	0.1385	1.72	7.46	92.54	15.1	55.25	9.06	0.16
	chard	wangdi	25/10/98	2	37.39	37.39	1.617	0.0865	1.53	5.35	94.65		52	0	0.00
	dark green	wangdi	27/09/98	2	31.60	290.86	0.64	0.0405	0.60	6.33	93.67	17.5	45.75	10.5	0.23
	mgreen	wangdi	01/11/98	2	26.98	342.77	0.487	0.0361	0.45	7.41	92.59	19	54	11.4	0.21
Mushroom	chantarelle	wangdi	06/09/98	56	646.26	774.97	0.72	0.06	0.65	8.67	91.33	13.3	30.75	7.98	0.26
	white lg hood	wangdi	06/09/98	20.5	363.97	509.06	0.9765	0.055	0.92	5.63	94.37	13.3	30.75	7.98	0.26
	chantarelle	lobesa	14/08/98	40	869.57	869.57	0.5	0.023	0.48	4.60	95.40		14.75	0	0.00
	ramaria	wangdi	09/08/98		0.00	0.00	1.5	0.0842	1.42	5.61	94.39		20	0	0.00
	shitake	wangdi	11/08/98	100	1266.58	1266.58	1.4515	0.1146	1.34	7.90	92.10		37	0	0.00
	shitake	wangdi	16/09/98	100	739.23	756.70	3.759	0.5085	3.25	13.53	86.47	14.8	36.5	8.88	0.24
	yellow button	wangdi	01/11/98	30	317.57	567.57	0.4827	0.0456	0.44	9.45	90.55	19	54	11.4	0.21
	white lg hood	wangdi	01/11/98	28	249.55	361.64	0.9064	0.1017	0.80	11.22	88.78	19	54	11.4	0.21
Brinjal		RC Bajo	17/06/98		0.00	83.21	1.3655	0.137	1.23	10.03	89.97	19	49.5	11.4	0.23
		RC Bajo	17/08/98		0.00	120.00	1.0865	0.095	0.99	8.74	91.26	19	49.5	11.4	0.23
		RC Bajo	19/08/98		0.00	123.55	0.7753	0.0743	0.70	9.58	90.42	15.3	45.5	9.18	0.20
		RC Bajo	19/08/98		0.00	56.24	1.8	0.1643	1.64	9.13	90.87	15.4	46	9.24	0.20
		RC Bajo	19/08/98		0.00	125.77	0.6717	0.0749	0.60	11.15	88.85	15.7	46.5	9.42	0.20
		RC Bajo	19/08/98		0.00	128.97	0.506	0.0749	0.43	14.80	85.20	16.1	47	9.66	0.21
	Pplong	wangdi	09/08/98		0.00	0.00	1.75	0.1284	1.62	7.34	92.66		31.5	0	0.00
	Dark purple	RC Bajo	30/07/98		0.00	0.00	3	0.265	2.74	8.83	91.17		43.75	0	0.00
Medicinal	Abimoshis	RC Bajo	19/08/98		0.00	590.08	0.1182	0.0121	0.11	10.24	89.76	11.9	18	7.14	0.40
Tomato	roma	wangdi	17/08/98	15	268.52	352.47	2.175	0.1215	2.05	5.59	94.41	17	50.25	10.2	0.20
	roma	wangdi	09/08/98		#DIV/0!	#DIV/0!	1.75		1.75	0.00	100.00		62.5	0	0.00
	roma	wangdi	26/07/98	10	101.45	121.62	3.5	0.345	3.16	9.86	90.14	11.6	30.5	6.96	0.23
	cherry	thimphu	16/09/98	20	268.04	377.61	1.8495	0.138	1.71	7.46	92.54	25.2	68.5	15.12	0.22
	roma	wangdi	20/07/98	9	115.35	149.18	4	0.3121	3.69	7.80	92.20	17.6	47.25	10.56	0.22
Radish	Tokinashi	wangdi	15/08/98	5	70.82	221.97	1.473	0.104	1.37	7.06	92.94	26.2	65.75	15.72	0.24
Pumpkin	Large green/yellow	punakha	15/08/98	4	39.96	154.70	1.3685	0.137	1.23	10.01	89.99	26.2	65.75	15.72	0.24
		wangdi	06/09/98	1.5	22.14	64.32	4.2	0.2845	3.92	6.77	93.23	20	56.25	12	0.21
	long green	wangdi	22/09/98		0.00	22.15	6.6155	0.596	6.02	9.01	90.99	22	68.5	13.2	0.19

Crop	Variety	Source	Date Start	Price fresh / kg	Price dry / kg	Price Dry + Drying Cost / kg	Weight Start kg	Weight Finish kg	Weight Loss kg	Finish %	Loss %	Metre Use kwh	Total Time hr	Power Cost	Cost / hr
	round	thimphu	25/09/98		0.00	200.00	0.91	0.12	0.79	13.19	86.81	40	68.7	24	0.35
Beans	Borlotto	punakha	15/08/98	12	80.97	141.89	1.3225	0.196	1.13	14.82	85.18	19.9	52.75	11.94	0.23
	green	wangdi	20/09/98	13	114.72	201.04	1.509	0.171	1.34	11.33	88.67	24.6	66	14.76	0.22
	green	wangdi	25/10/98	10	120.19	120.19	0.637	0.053	0.58	8.32	91.68		52	0	0.00
Carrot	Enantes	punakha	15/08/98	10	102.68	296.83	0.6315	0.0615	0.57	9.74	90.26	19.9	52.75	11.94	0.23
Chili	Local	wangdi	10/08/98		0.00	0.00	0.5	0.0616	0.44	12.32	87.68		46.25	0	0.00
	CARD III	RC Bajo	02/08/98		0.00	351.83	1	0.0955	0.90	9.55	90.45	56	265.5	33.6	0.13
	Begup	wangdi	02/08/98		0.00	336.00	1	0.1	0.90	10.00	90.00	56	265.5	33.6	0.13
	Korein	RC Bajo	02/08/98		0.00	0.00	0.715	0.145	0.57	20.28	79.72		186.5	0	0.00
	Sha ema	wangdi	20/09/98	13	97.01	138.71	1.847	0.2475	1.60	13.40	86.60	17.2	46.5	10.32	0.22
	Sha ema	wangdi	15/11/98	33	239.92	286.85	0.9015	0.124	0.78	13.75	86.25	9.7	30.5	5.82	0.19
	Sha ema	wangdi	24/09/98	15	114.41	198.95	2.723	0.357	2.37	13.11	86.89	50.3	89	30.18	0.34
Banana		wangdi	27/09/98		0.00	107.06	0.4715	0.1345	0.34	28.53	71.47	24	65.5	14.4	0.22
Banana		wangdi	11/08/98		0.00	0.00		0.076	-0.08	#DIV/0!	#DIV/0!		50.5	0	0.00
Broccoli	Desico	punakha	15/08/98	45	454.90	454.90	0.9755	0.0965	0.88	9.89	90.11		35	0	0.00
Mango		lobesa	15/08/98	30	202.98	202.98	0.4195	0.062	0.36	14.78	85.22		40	0	0.00
	small	wangdi	27/09/98	30	192.29	292.29	0.923	0.144	0.78	15.60	84.40	24	65.5	14.4	0.22
Meat	yak	thimphu	19/09/98	120	467.05	483.22	4.0711	1.046	3.03	25.69	74.31	28.2	71.5	16.92	0.24
Meat	yak	thimphu	15/09/98	100	316.01	328.17	4.116	1.3025	2.81	31.64	68.36	26.4	71.25	15.84	0.22
Basil	german	lobesa	15/09/98		0.00	271.84	0.3725	0.0245	0.35	6.58	93.42	11.1	33.25	6.66	0.20
Cheese	Bumthang	Bumthang	05/09/98	150	225.28	286.96	0.6135	0.4085	0.21	66.59	33.41	42	108.5	25.2	0.23
	Local	wangdi	20/09/98	82	224.55	274.29	0.6805	0.2485	0.43	36.52	63.48	20.6	42.75	12.36	0.29
	Local	punakha	26/09/98	100	241.87	284.68	0.9965	0.412	0.58	41.34	58.66	29.4	80.25	17.64	0.22
Persimom	local	wangdi	21/09/98	20	125.93	269.05	1.003	0.1593	0.84	15.88	84.12	38	70	22.8	0.33
	Local	punakha	05/10/98		0.00	38.10	0.7315	0.1575	0.57	21.53	78.47	10	23	6	0.26
	Local	punakha	28/09/98	6	40.46	99.55	1.116	0.1655	0.95	14.83	85.17	16.3	47.5	9.78	0.21
Onion	Spring	wangdi	15/11/98	7	58.98	161.94	0.7415	0.088	0.65	11.87	88.13	15.1	55.5	9.06	0.16
Coriander	Local	wangdi	15/11/98	10	97.95	396.41	0.191	0.0195	0.17	10.21	89.79	9.7	30.75	5.82	0.19
Dill	German	wangdi	14/11/98		#DIV/0!	#DIV/0!			0.00	#DIV/0!	#DIV/0!	24.5	58.5	14.7	0.25

Appendix 6: Inventory of sub-tropical fruits at RNRRC-Bajo.

Crop	Type	Cultivar
Citrus	Mandarin	1.Oota-Ponkan 2.Kishu 3.Freemont 4.Encore 5.Clementine Nules 6.Local
	Satsuma Mandarin	1.Ichifumi Wase 2.Miyagawa Wase 3.Okitsu Wase 4.Matshuda Unshu
	Tangelo	1.Minneola 2.Seminole 3.Murcott
	Tangor	1.Miyauchi Iyo 2.Iyo
	Sweet orange	1.Navel Late 2.Lane Late 3.Valencia Olinda 4.Washington navel
	Sour orange	1.Gon ton 2.Bouquet de Fleur
	Lime	1. Bearss (seedless) 2. Local 3. Muratlime (Combavas)
	Lemon	1. Limoniera 2. Meyer
	Grape Fruit	1.Rio red 2.Star ruby
	Pumello	1.Ortoblanco 2.Langthel trongsa
	Kumquat	1. Marumi

	Limquat	1. Evstis
	Rootstock	1.Troyer citrange 2.Carrizo citrange 3.Rangpur lime 4.Cleopatra mandarin 5.Rubidox trifoliate 6.Rough lemon
Avocado	Cultivar	1. Zutano 2. Hass 3. Bacon 4. Pinkerton 5. Fuerte
	Rootstock	1. Giles 2. Peruque 3. Hodge 4. Green river
Grapes	Table	1. Muscat of Alexandria 2. Calmeria 3. Ruby seedless 4. Sultana M12 5. Waltham 6. Early steuban 7. Portlands early
	Wine	1. Chasselas 2. Perlette 3. Muscat 4. Pinot Blanc 5. Pinot Noir 6. Chardonnay 7. Cab Franc 8. Reisling 9. Mondeuse 10.Gamay N
Peach	Cultivar	1. Shan-I- Punjab 2. Floradsun 3. July Elberta
	Rootstock	1. GF 677 2. Local peach
Apricot		1. New Castle 2. Kaisha
Pear		1. Gala 2. Tsirang Local 3. Flemish beauty

		4. China
ST Apple	Cultivar Rootstock	1.Anna 2.Eichmeir (polliniser) 1.MM III
Walnut		1.Kagzi(Indian soft shell)
Almonds	Cultivar	1. Drake 2. Kagzi 3. Texas 4. Pathak wonda 5. Debor badam 6. Thin-shelled ?
Mango	Cultivar	1. Dasheri 2. Langra 3. Chausa 4. Amrapalli 5. Himsagar
Guava	Cultivars	1. Allahabadi safedi 2. Thai giant 3. HM 4. Local
Pomegranate		
Walnut		
Pecan		
Banana		
Chestnut		
Strawberry		
Fig		

Appendix 7: Location and experiment data sheet.

1. Location Data:

A. Name:RNR-RC, Bajothang Altitude: 1300 masl

B. Soil Texture and pH: Sandy loam

C. Previous Crop: Fallow

D. Environment during growing seasons (hot-wet, hot-dry, cool-dry, etc.): hot-dry and hot-wet.

2. Experiment Data:

A. Sowing date: 9th March 1999

B. Transplanting date: 5th May 1999

C. Harvest dates: 7th July, 22nd July and 30th July 1999

D. Seedling management system: In shade house on raised beds (burnt straw prior to sowing) with 2cm plant to plant and 15cm row to row spacing.

E. Number of plants/ plots Trt.I: 24 Trt.II: 14 cm

F. Distance between rows Trt.I: 20 cm Trt.II: 50 cm

G. Distance between plants within rows Trt.I: 15 cm Trt.II: 50 cm

H. Plant population density (plants/ ha)Trt.I: 160000 Trt.II: 40000

I. Plot dimensions Trt.I: 6 m x 2.5 m Trt.II: 6 m x 1 m

J. Herbicide(s) used, and when applied: NA

K. Insecticide(s) used, and when applied: NA

L. Fungicide(s) used, and when applied: NA

M. Special management practices used, if any: Two hand weeding:
1st on 28 May 1999 and
2nd on 14th June 1999.

N. In your opinion, considering yield, plant type, fruit acceptability to local consumers, and other factors, which are the best 5 chilli lines?

Appendix 8: Visitors during July 1998 to June 1999

Date	Visitor Name	Purpose
14/9/98	Dr. Edwin Javier and Dr. S.S Baghal	Review of breeding program and seed policy
17/9/98	Janette Mauritz, UNDP, Program Officer	Site visit/familiarisation
5/10/98	IRRI/SDC/IDRC Review Team	Mid Term Review of IRRI-Bhutan project
14/10/98	HE Peter F. Walker, Canadian High Commissioner	Familiarisation visit
15/10/98	G.C Loresto, GRC, IRRI	Rice Biodiversity Training
16/10/98	Bente Herstad, Head of Biodiversity and Conservation Asia Program Trygve Berg, Scientist Associate, BUCAP	To explore the possibility of including Bhutan as a partner of BUCAP
27/10	FECSU and BBS Team	Collection of information
1/11/98	John Gullet	Station visit regarding horticulture
1/11/98	Dr. John Gulette, Acting Director, Holland	Familiarisation visit
3/11/98	Drake Hocking, Agro-forestry Consultant	Seminar on Agro-Forestry
4/11/98	Dr. Toby Gooch, IHDP	Cost Benefit Analysis Seminar
21/11/98	John Copland, ACIAR and Dr. J.B Gurung, Serbithang	Familiarization Visit
23/11/98	David B.Parsons, U.K.	Fimiliarization Visit
8/1/99	Fresh Graduates (47)	Familiarization tour

Appendix 9: Seminars, meetings and trainings

Date	Officials	Purpose
29/10/ to 7/11/98	Pema Dorji, Research Officer	Participated in SAIC Meeting at Bangladesh
29/10 to 30/11/98	Sangay Duba, Research Officer	Study tour to ICIMOD, Nepal
7/10 to 19/11/98	Jigme Norbu, AEPO	Training on Extension in Bangladesh
13/10/98	Dawa Delma, Inspector	Training on Legume in Thailand for 5 months
	Karchung, D.D Chettri, Ugyen Tshering, Jigme Norbu, Nidup Tshering	Study tour to India
7-9 Jan'99	Sherub Gyaltshen, Acting Director, REID W. Roder, RNRRC Jakar N.K Pradhan, NPPC Padam Giri, RNRRC Yusipang Sonam Norbu, RNRRC Jakar T.R Gurung, RNRRC Khangma V. Moktan, RNRRC Khangma T.B Katwal, RNRRC Yusipang Christopher, SSF&PNM	Attended Field Crops Co-ordination Meeting
11-13 Jan '99	Acting Director, REID; Dzongkhag (Wangdue, Punakha, Gasa, Tsirang, Dagana) RNR Sector Heads and Planning Officers; representatives of Central Programs and Projects	Attended 5th Review and Planning Workshop

Appendix 10: Financial report for the fiscal year 1998-99

Object classification	Amount in Nu.
Personal emoluments	2932202.83
Other Personal emoluments	650829.00
Travel	694562.00
Utilites - telephone	45186.75
Utilities - telex/fax	19447.00
Utilities - electricity	48652.67
S&M - office supply	30794
S&M - fertiliser	19868.00
S&M -seeds/seedlings	5200.00
S&M -Uniform/extension kits	45590.00
S&M - textbooks/journals	6252.00
S&M - other supply	5645.00
MOP - building	2250.00
MOP- vehicle	433808.71
MOP - equipment	62787.90
Operating exp - Conference	125390.30
Operating exp - tax/duty	395.00
Govt. PF contribution	174530.00
Exp. On stracture - building	190772.00
P&E - general tools/instruments	---
TOTAL	5494163.41