ABOUT THIS REPORT

This is the fifteenth technical report produced from this Centre since 1984. Unlike the earlier reports that were based on calendar years, the present report follows the RGOB's financial year that runs from 1 July to 30 June. This report refers to crops sown in November 1997 and harvested in April-May with respect to winter crops like wheat, oil crops and vegetables. The summer crops are mostly planted in June-July and harvested in October-November. Some experiments are reported completely while others are ongoing and interim results are reported.

This report follows the style of the preceding reports, wherein program-wise presentation is followed. For instance, results from the Field Crops research are presented followed by Horticulture, Livestock, Forestry and Systems Resource Management.

Abbreviations used in this report are listed in the following pages. The report uses the International System of Units (SI) with few 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. Separations of means in a table are usually by Duncan's Multiple Range test at 5% level of significance, unless otherwise stated.

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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 co-ordinating 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, 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 EPINARM project, IHDP, RNR-ESP, BG-SRDP, SSF & PNM and other development projects of the region.

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Thinlay	-	Night Guard

* Completed assignment/transferred.
+ Newcomers.

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

EXECUTIVE SUMMARY

FIELD CROPS

Field crops research aims to increase and sustain the productivity of cereals (rice, maize, wheat, and other minor crops), oilseeds (mustard) and grain legumes in the long run. The short-term objectives are to identify, adapt or develop appropriate and affordable technologies/varieties 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, 21 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 IR62467-B-R-B-8-B and CARD20-21-3-2-3-1-1performed well compared to IR 64. Local check Zakha yielded 4.47 t/ha. The IET was composed mainly of breeding lines aimed to identify suitable varieties for further evaluation. Analysis showed that several test varieties produced significantly higher grain yields than Zakha. However, none of the entries could perform better than IR 64. The elite selection from this trial will be further evaluated in the following season.

Two sets of Observation Nursery were established. In the first set, grain yields 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 133-154 days, while the plant height ranged from 68-162 cm. No notable insect pests and diseases were observed in the trial. The second set consisted of 120 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. Estimated grain yield ranged from 0.84-12.0 t/ha; plant height from 71-131 cm and days to 50% flowering from 101-143. Selected entires will be further assessed.

The on-farm research included PRET trials that were limited to only a few locations due to insufficient seeds, precluding a formal analysis. From site averages, IR56346-1-1-2-1-9-1-1 gave the highest yield from among the test entries and scored high on farmers' preferences in Zomi because of its high yield and acceptable straw yield. Five high-altitude, cold-tolerant and blast resistant rice lines from the Genekha breeding program of RNRRC Yusipang were also evaluated in the high elevations of Gasa, Punakha and Wangdue (data submitted to RC-Yusipang for analysis and reporting).

A rapid survey of rice double cropping in the Wangdue-Punakha valley was done. Rice double cropping is still continued in small scale in several geogs. Farmers use different rice varieties for double cropping such as No.11, IR 20913, IR 64 and Sangay Rinchen. Majority of farmers growing two rice crops are share-croppers, and they usually do to supplement food shortages. A gradual decline in rice double cropping acreage is not attributable to technology failure, but due to other factors

such as share-cropping, damage by wildboars, birds and rodents, labour and irrigation scarcity etc.

Collection, characterisation and rejuvenation of rice germplasm are considered as important activities in variety development. In 1999 a total of 111 local rice varieties from different altitudes were rejuvenated and characterised at the station.

Grain Legumes

Although legumes are not presently very popular in the rural Bhutanese diet especially in the western parts, research is being carried out to tap their potential as a source of cash generation and restoration of soil fertility. In 1999-2000, variety evaluation was carried out on mungbeans. VC6173 B-6, VC 6368, VC 3960-89 and VC 6375 were identified as promising varieties.

Crop Management Research

Research on crop production management included the yield optimisation of selected released rice varieties, and organic crop production using a combination of organics and Effective Microorganisms (EM).

With the objective to maximise/optimise the yield of improved rice varieties using two fertility levels, 80-40-20 NPK kg/ha + FYM 20 t/ha (L1) and 120:80:30 NPK kg/ha + FYM 10 t/ha (L2), 6 rice varieties were subject to a factorial RCBD with 3 replications. Results showed that there were significant variety and fertility level effects, but the variety x fertility level interactions were insignificant. Of the two fertility levels L2, which is almost doubling of the NPK, produced an average 1.13 t/ha more grains than L1, reflecting an overall response of the improved varieties to additional fertilisation. Averaged across fertility levels, variety BK-2 yielded the highest at 10.48 t/ha, a 4% increase from the popular variety IR64. BK-2 also showed the maximum responsiveness to higher fertilisation. These results suggest that rice yields could substantially be increased using a higher dose of NPK in the presence of adequate organic materials such as FYM.

Preliminary and indicative results from the use of EM in cereals (rice, wheat, mustard and maize) showed that moderate yields could be obtained without chemical fertilisers. Improvements in the physical and nutritive qualities of the soil are also becoming evident. However, detailed analytical and economic assessments remain to be done.

HORTICULTURE

SUB-TROPICAL FRUITS

The period July 99 to June 2000 was one in which fruits research saw gradual progress in previousely-initiated work viz. varietal evaluation and propagation programme The season also saw the introduction of five new cultivars of mandarin through the auspices of the Citrus Improvement Project of the JG.AG Foundation. The new mandarin cultivars came in the form of bud-woods and are being propagated further to obtain sufficient quantity for establishing an adaptability trial of

their own. Steady progress was seen in improving the research facilities too. The propagation programme benifited immensely by constructing a plastic house, in terms of being able to extend the period of budding process. Irrigation facilities have been also improved with the construction of the second pump leading to fruits research site.

The period also welcomed the transfer of Mr.Tsheten Lhendup from RNRRC Yusipang to this centre. The fruits research benifited immensely from his vast experience in plant propagation and also his knowledge in sub-tropical fruits cultivation.

In addition to the research results reported in the 98-99 report, new results have been generated in pecan and some citrus. On-farm evaluation of the promising cultivars have been further strengthened with the establishment of three demonstration orchards at three elevations in two dzongkhags. All the above promising cultivars have been planted in these orchards and monitoring is done at regular intervals. Three more demo orchards are in the process of establishment in three other Dzongkhags. Five more demonstration orchards are in the pipeline for the region and shall be established next season, bringing the total number of established demo orchards to eleven ultimately. The on-going trial to ascertain if poor management is the cause of the declining citrus orchard at the Phuntsho Pelri Palace orchard is being continued. A Technical team has been constituted to oversee the management in an integrated manner. New areas of work in on-farm trial include persimmon budding trial at Nobgang, lime top-working at Shengana, cardamom varietal and drying trials at Tsirang.

Propagation of new materials and promising cultivars received maximum attention, to bolster speed and quantity, to enhance the process of establishing the materials soon in trials and demo orchards. New methods have been also generated in walnut grafting. Banana-grafting and tongue grafting in March has been deduced as the most reliable form of field propagation for walnut. Avocado grafting, however, suffered a setback due to lack of mature scion-woods.

Equal efforts have also been put in collecting the local indigenous 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, which are available for trial use as rootstocks for the improved cultivars imported from California through IHDP-II. A start has been also been made to collect the superior strains of our local mandarin from different parts of the country and propagate them vegetatively on selected improved rootstocks. Efforts are also made 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.

VEGETABLES

Based on the Regional Research Program Profile for the 8th FYP, the main objective of vegetable research involves in the diversification of vegetable crops with emphasis on high value crops that would meet both nutritional and cash income requirements of the farmers. Efforts will be made to increase local off-season production to replace imports. These objectives can be realised through the introduction and evaluation of

exotic species besides the evaluation and improvement of local germplasm. Production management (crop establishment, pest control, nutrient management – organically grown) crop rotation, intercropping and kitchen gardening would also be given adequate research attention.

The workplan was prepared keeping in mind the above objectives. This report covers all the planned activities starting July 1999 till June 2000. The activities proposed during the 5th Regional workshop have been subject to some changes as a result from the discussions and requirements from the Dzongkhags. A few activities have been incorporated to address farmers' concerns.

General Activities were as follows:

On-station

Germplasm evaluation / production trials for various vegetables; Production trials for SAVERNET, linking with on-farm trials; Production trials for CIP / IPDP potatoes, linking with on-farm and national programme; Asparagus trials and nursery production, regional dissemination, link to commercial sector; Exploitation of greenhouse technologies, production intensification, off season production; Cost-benefit analysis, introduction to research protocols, links to on-farm and off-station; Testing DSC seeds for quality; and seed production and maintenance

On-farm

Farmers fields trials (FFT) for SAVERNET crops, linking with on-station trials; FFT for CIP / IPDP, linking with on-station and national Programme; and asparagus extension throughout region

Off-station

Marketing studies; ad hoc support to Dzongkhag administrations throughout region; surveys; and germplasm collection

LIVESTOCK

The main objective of the livestock research program is to develop more productive and sustainable livestock options for the wetland farmers and strengthen crop-livestock systems research. On-station activities include the trial on nursery tree species, sugarcane accession and evaluation, tree fodder seed production and development of a demonstration tree fodder plantation. *Sesbania sesban* has been identified as the best species in terms of height and diameter growth among about 20 species tested. "Tandin Bajo" and Zingsay White" are the two best performers in terms of height among the sugarcane varieties tested. The trial on fodder seed rate was not very successful and would need to be continued to deduce a reliable seed rate under the conditions prevailing in the region.

On-farm activities included a stall feeding survey at Tsirang and a trial to produce legume forages in orchards. The findings of the survey reveal that the breed type and land topography plays an important role in the adoption of stall feeding practices.

Also in general, for a farmer to adopt stall-feeding practice, he/she should have keen interest, family labour, feed resources and keep a maximum of three heads of pure-line Jersey cows to be profitable. Pintoi and GLD were tried against a control in the legume in orchard trial. Pintoi is doing well while GLD has failed.

A survey to ascertain the breed preference for dairy production in the Gasa Dzongkhag was also conducted by the sector. The survey points out that the farmers of Khamae and Khatoe are increasingly looking for a change from *F1* level crosses of *Mithun* and *Thrabam* to *F2* level crosses of Jersey and Brown Swiss. Also, the new breeding technique appears technically sound, economically efficient and socially acceptable.

FORESTRY

With the identification of two Forest Management Units (FMU) for research namely Khotokha and Rimchu the Forestry Program of the centre has made modest attempts into mainstream forestry research in 99-00 fiscal year.

The sector continued with the activities at the centre such as the introduction and evaluation of multipurpose tree species (MPTS), development of vegetative techniques for promising species, comparison of the various methods of bamboo propagation techniques and performance evaluation of some exotic leguminous species.

In the Lingmutey Chu watershed the community forestry nursery is being maintained to generate planting stock for future planting. About 3.04 hectares and 2 ha. of community forestry plantation have been planted at Omtekha and Wanjokha respectively in collaboration with the communities. To monitor the resource use and dynamics of the forest in the watershed, eight permanent sample plots have been established. A rapid silvicultural assessment (RSA) was also conducted to to elicit through discussions with the community focus groups on their perception of the forest quality and quantity and verify these briefly in the field.

The stand stability trial has finally materialised in the Khotokha forest management unit (FMU) while discussions for the collaborative research work between the Natural Resources Training Institute, RNRRC, Bajo and RNRRC Yusipang has been continuing co-ordinated by the BG-SRDP Lobeysa. Detailed roles and responsibilities of the agencies involved, research themes of interest and a work plan will be developed in due course.

SYSTEMS RESOURCE MANAGEMENT

CBNRM

CBNRM was further continued in the Lingmuteychhu Watershed during 1999-2000.

Under the crop production and management research a trial on on-farm paddy variety for high altitude was initiated in collaboration with the RNRRC, Yusipang. Four sites in the Lingmutey Chu watershed were chosen to study farmers' evaluation of the four released rice varieties and campaigns on shochum control through intensive hand

weeding was carried out. Asparagus seedlings were also distributed to the villages of Dompola, Thangu and Wangjokha to promote asparagus growing in these areas.

To enable evaluation of station-proven planting materials in farmers' fields, a demonstration orchard have been established in an area of one acre at Omtekha. A total of 67 fruit plants has been planted and includes citrus, sub-tropical apple, chestnut, apricot and pomegranate.

The mithun bull placed at Nabchee village in April 1999 is being monitored by the sector. The bull is now about two and half years old. Temperate pasture seed mixture consisting of Cocks foot, Italian Rye grass, Tall fescue and White clover was provided to the community to develop pastureland for the bull.

IPNS

Research and development work on IPNS (Integrated Plant Nutrient Systems) started at Bajo in 1990 with major impetus only in early 1997 with the commencement of Community-Based Natural Resources Management (CBNRM) research. In May 19997, 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). Research under this program is being continued, as it is one of the important research themes in CBNRM.

The trials were aimed to work closely with farmers in a participatory manner to improve their soil fertility management systems using an integrated plant nutrient system (IPNS) approach to improve the productivity of the land without depleting the soil resources.

Several follow-up visits were made over the subsequent months in those sites. During these visits, the available IPNS technologies were matched with the soil fertility problems and production priorities of the different soil fertility management category test farmers'. These were presented to the farmers in full (characteristics, management requirements, uncertainties, predicted advantages and possible disadvantages) and the farmers individually selected those that they wished to try as a test activity. Their priority problems and chosen activity results were presented here in this report with recommendations and future directions for each tested technology wherever possible. Out of watershed a rice crop cut exercise was conducted in Rinchengang, where rice fields are used very intensively.

Overall, to improve the coverage of farmers and their awareness of soil fertility management issues, farmer training in IPNS using a modified Farmer Field School approach is established with main emphasis on fertilizer use on rice crop. Same approach will be use for maize trash lines in Nabchh community.

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 1999-2000 was concentrated on *Shochum* Control

Campaign, integrated disease management (IDM) of potato via farmer field school (FFS) approach, *Parthenium* weed Control Campaign, citrus fruit fly control and literature reviews for *Parthenium* weed. A trial on chilli blight control by fungicide was also conducted in farmer's field but the crop cut could not be done as the chillies were destroyed by cattle and deer. Similar trials with proper fencing will be conducted in the coming year in farmer's field.

Potamogeton distinctus (Shochum) is a noxious perennial aquatic weed infesting wetlands. To promote intensive weeding and awareness amongst the farmers a Shochum control campaign was conducted in collaboration with extension staff of Wangdue. Two sites – one in Gaselo and one in Lingmuteychu were selected and three intensive weedings done. At harvest, field days were conducted and crop cuts were done jointly with extension agents and the collaborating farmers. The collaborating farmers and a few others were also taken on a 2-day tour to Paro where they could see the rice fields free of Shochum. This was done in order to increase the awareness of Punakha- Wangdue valley farmers on the control aspects of Shochum and to demonstrate that intensive weeding can eradicate this noxious weed in due time.

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 FFS is implemented in ten potato-growing areas of Phobjikha. This approach involves and educates the farmers through out the crop production process. It not only deals with a particular disease, but also emphasizes on crop sanitation to help minimize other problems as well.

Realizing the fact that parthenium weed (*Parthenium hysterophorus*) an exotic weed introduced via India probably as seed contaminants can cause more of health hazards than agricultural nuisance intensive parthenium weed management and awareness campaigns were conducted in and around the Wangdue valley. While the centre conducted the weeding campaign in the farm area other institutions were also informed and encouraged to mobilize similar activity in their areas. To promote national awareness, a one-day meeting on controlling parthenium weed was jointly organized by NPPC, Semtokha and RNRRC, Bajo on 24 August 00 at RNRRC, Bajo. The staff from NPPC, Semtokha, RNRRC, Bajo and representatives from other institutions in Wangdue attended the meeting despite short notification for the meeting. Similar campaign is expected to continue in the coming year.

On the citrus fruit fly control the proper timing of bait splashing still remains doubtful as the emergence of the adult flies differs across agro ecological zones. In keeping with the objective to develop a viable control method for the fruit flies that cause citrus fruit drop, a trial was conducted in Tsirang to determine the efficacy of different liquid lures and emergence period of adult flies. Since the trial is on going, with the exception of raw data collected so far, the complete results and conclusions will be prepared jointly with NPPC at Semtokha.

AGRICULTURE ECONOMICS

The two major activities of the Agriculture economics sector were economics of rice production and use of sanbird to control sochum.

The study on the economics of rice production was conducted in 1999 with a total of twelve farmers from two selected villages of Dompola and Wangjokha villages in the Lingmuytey Chu watershed. Eighty three percent of total cost consisted of labour cost while material inputs costs formed only 9%, and costs of ploughing accounts for only 8% of the total costs. The average cost of production of milled rice was Nu. 13.90/kg and total average cost of production was Nu. 25,000 per hectare. Returns to land were calculated at Nu. 24,714 per hectare and the average return to labour was Nu. 143/day.

The study on the economic feasibility of the use of Sanbird to control Shochum showed that the annual added costs of applying Sanbird from year 1-5 were Nu. 23020/ha and the benefits accrued from it was Nu. 24,358/ha. Applying Sanbird increased gross benefits by Nu. 24,358/ha. Increase in rice yield contributed a major per cent of the benefits. The marginal rate of return (MRR) is 41% which is not economically attractive because if a technology is new to the farmers and requires that they learn some new skills, a minimum of 100% MRR is recommended.

Besides the above activities the sector also carried out a crop budgeting of winter crops in the watershed, a market appraisal study, weekly price data collection and RNR data validation.

WATER MANAGEMENT RESEARCH

Irrigation Scheduling for Citrus and Intermittent Irrigation Technique for Paddy are the two major outputs from Water Management Research (WMR) apart from other activities for the year. Other activities in Lingmuteychu Watershed such as collection of rainfall data, water-balance study, evaluation of new water sharing system in Dompola, vegetative stabilisation of channel/gully has all been successfully executed while at the national monitoring and collection of moisture balance for citrus and apple have been continued. Rainwater harvesting for irrigating high value winter crop in Gelephu has been implemented.

As part of the outcome of soil moisture balance study of citrus conducted over the last couple of years, WMR has now collected adequate data to embark on to the next stage of scheduling irrigation for citrus. It has been observed that farmers just for the sake of irrigation apply water to their plants irrespective of plant water requirements and timing. Some farmers even complained that after they have started irrigating the yield has reduce tremendously and in some cases there is hardly any fruit to be seen on the tree. This is due to the fact that farmer are not aware of the reason that citrus need a stress period of two months [January and February] before the budding. This stress can be either in the form of moisture stress (water deficit), cold stress (low temperature) or chemical stress (when stress through moisture stress is not adequate application of Paclobutrazol @18g/plant is required). In our context moisture stress is appropriate as there is no or minimal rainfall during these period. It was also

confirmed from the soil moisture balance study that the soil tension goes above 200 centibar, which is sufficient to attain moisture stress. Therefore, citrus should not be irrigated from October till end of February.
After the stress period is over or during the budding, flowering and fruit setting stages irrigation is a must if the rainfall is not sufficient to bring the soil moisture to field capacity (soil moisture tension below 30 centibars). Therefore irrigate citrus only from beginning of March till May depending on rainfall.

A study on improved water management practice or intermittent irrigation method for paddy was conducted in view of improving water use efficiency in production of paddy and to reduce conflicts/frictions among farmers & water user groups in sharing the resource due to water shortage problem. The result of the three years research on-station and one year on-farm has indicated that water efficiency can be improve by 30% without significant reduction in yield. The result implies that some conflicts related to water-shortage can be minimised, 30% increase in wetland can be achieved in places where the expansion of wetland is limited by shortage of water previously. Problems like leaching of soil nutrients, pollution of watercourses by chemical flowing out the fields and soil erosion related to continuos flooding can be minimised (existing farmers management practice) by adopting intermittent irrigation method. Other hand saved amount of water can maintain minimal and continuos flow in the watercourse thus maintaining its ecological system as well.

Intermittent irrigation also helps to control aquatic weeds. This technique is very essential specifically in controlling in Shochum which otherwise is very expensive to control with chemical means. On the other hand intensive weeding is required.

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) and grain legumes (mungbean, soybean). The major focus of the program is on integrated germplasm development and the production management of the major 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 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. Fertilisers applied are 70-40-20 kg NPK/ha, with half the N topdressed at PI. Weeds are controlled using Butachlor and spot handweeding as necessary. Harvest and post-harvest operations are done manually to avoid seed contamination.

1.1.1.1 Advanced Evaluation Trial (AET)

In 1999, AET consisted of 21 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 (6.75 t/ha) although several crossbred lines produced yields comparable to IR 64. IR 62467-B-R-B-8-B, a cross of local Attey and Suweon 358, performed well. Local check Zakha yielded 4.47 t/ha. 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)
IR 64	6.75	83	124
IR62467-B-R-B-8-B	6.35	132	121
CARD20-21-3-2-3-1-1	6.09	89	124
IR63322-B-B-B-26-B	5.92	107	114
IR62467-B-R-B-10-B	5.60	131	121
IR65239-B-B-13-1-B	5.35	130	122
IR62470-B-R-B-14-1-B	5.32	141	122
IR62467-B-R-B-60-B	5.28	136	121
IR62467-B-R-B-29-B	5.22	126	114
IR62473-B-R-B-3-B	4.99	129	121
IR62467-B-R-B-12-B	4.86	127	122
IR62745-B-R-B-5-B	4.81	120	125
IR63332-B-B-B-25-B	4.79	112	114
IR62472-B-B-50-B	4.74	128	124
IR62467-BR-B-63-1-B	4.64	127	121
LOCAL ZAKHA	4.47	123	121
IR62467-B-R-B-64-1-B	4.14	134	123
IR65239-B-B-17-B	4.07	102	123
IR62467-B-R-B-34-2-B	4.03	134	125
IR62470-B-R-B-14-2-B	3.42	130	124
IR62467-B-R-B-73-1-B	3.38	135	123
CV%	16.7	3.3	0.8
S.E.D.	0.68	3	1

1.1.1.2 Initial Evaluation Trial (IET)

A set of IET was 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.

The trial 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 of variance 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 113-125 days. Likewise, plant height ranged from 76-148 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

Variety	Yield (t/ha)	P.ht (cm)	50% Flw (days)
IR 64	6.44	85	124
IR65239-B-B-7-1-B	6.20	126	121
IR62745-B-R-B-20-1-B	5.87	110	119
IR62467-B-R-B-F8-1-B	5.72	129	121
IR65239-B-B-68-1-B	5.56	121	125
IR62467-B-R-B-F60-1-B	5.36	135	121
IR62467-B-R-B-24-1-B	5.32	138	121
IR62473-B-R-B-24-2-B	4.97	117	121
ZAKHA	4.91	122	123
IR62473-B-R-B-30-2-B	4.84	120	121
IR62467-B-R-B-69-2-B	4.72	120	113
IR62473-B-R-B-30-3-B	4.69	117	121
IR62745-B-R-B-5-1-B	4.56	112	119
IR62472-B-B-31-1-B	4.56	76	123
IR62470-B-R-B-86-2-B	4.23	148	119
IR62467-B-R-B-35-3-B	4.22	129	121
IR62473-B-R-B-30-1-B	4.11	116	123
IR62470-B-R-B-82-2-B	3.97	123	120
IR62467-B-R-B-F49-1-B	3.95	139	123
IR62472-B-B-39-1-B	3.83	108	114
IR62467-B-R-B-35-2-B	3.70	138	122
IR62472-B-B-61-1-B	3.59	91	124
CV%	18.9	9.5	1.7
S.E.D.	0.74	9.2	1.7

1.1.1.3 Observation Nursery I

Cross-bred lines from different populations as well as introductions 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 inTable 3. 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 133-154 days, while the plant height ranged from 68-162 cm. No notable insect pests and diseases were observed in the trial. The selected entries will be further evaluated in replicated yield trials.

Table 3 Agronomic traits of entries in Observation Nursery 1999

Varieties	50% Flw (days)	Maturity (days)	Plant height (cm)	Grain yield (t/ha)
CNT87040-33-1-1	128	160	94	6.71
CNTLR85033-9-3-1-1	125	157	86	6.91
CNTLR85093-47-2-1-1	134	174	68	4.70
DELLA	114	146	115	4.34
DM24	134	174	95	3.71
DOM SOFOOD	115	146	140	2.51
DR92	124	156	90	7.16
FRX14F3B-14F6BF7	128	160	76	3.15
FRX92F3B-F4BF5	128	160	108	4.64
GAN-WAN-XIAN22	121	155	86	3.64
HASSANY	99	133	128	3.15
HEI BAO	89	120	72	1.81
IR62898-286-6-1	121	155	88	1.57
IR65638-169-3-2	121	155	79	4.44
IR65638-91-1-1	121	155	81	4.08
IR66229-45-3-2	121	155	97	3.16
IR66231-106-1-2	106	137	88	4.84
IR66231-127-1-3	106	137	86	4.65
IR66231-262-1-3	113	146	91	4.16
IR66231196-3-3	115	147	84	5.16
IR66232-75-5-1-2	115	147	95	4.07
IR66298-5-3-3-2-1	134	174	88	0.77
IR66696-49-1-2	113	145	90	4.59
IR67013-58-1-2	113	145	90	4.13
IR67410-174-1-2-1	121	155	84	2.97
IR67414-168-3-3-2	125	159	83	5.58
IR67415-272-3-4	121	154	77	5.38
IR67417-2-1-6	128	160	91	2.53
IR67418-100-2-1	121	152	91	2.42
IR67418-20-3-1-3-1	121	152	75	3.97
IR67420-206-1-2-3-2	121	152	83	4.34
IR67420-218-1-5-1	105	136	82	3.74
IR67894-40-1	128	160	115	3.75
PK3161	121	154	118	4.12
PK4553-42-1-1	-	-	162	-
SR6014-ZHONSHI4	124	159	94	3.64
T3	134	174	150	2.85
BASMATI370	121	154	115	4.05
KASHMIRI BASMATI	114	146	120	4.1
SPR85163-5-1-2-4	128	161	109	6.15
IR45138-131-2-1-1-3-1	121	155	90	6.54
IR72	122	155	84	7.34
M88	124	156	104	7.28
SPR88090-30-1-2-4	128	160	90	6.08
ITA222	134	174	78	5.61
VX83	134	174	79	4.85
NR11	128	159	87	6.69
RP1667-301-1196-1562	121	155	92	4.81

SPR85089-2-1	134	174	99	3.84
PS285048-19-3-1-1	142	174	85	4.61
IRGA318-11-6-9-2	124	159	89	5.41
RP2240-86-84	134	174	81	3.95
IR58185-23-3-3-1	134	174	107	3.96
X21	124	156	88	6.61
CT61163-8-9-5-2-M-2-M	128	160	90	6.09
RHS330-25-CX-3CX-4CX-02A	124	156	97	7.72
CT8240-15-3P-21-11-21	121	153	88	5.01
X20	128	160	99	6.87
PSBRC2	134	174	78	4.01
RP2235-63-42-7	124	156	83	6.68
NAR151FS-4-3	121	155	80	5.30
MIANXING7	128	160	81	5.1
ALTO MAYO 88	128	160	80	3.51
BR4829-28-2-4	134	174	117	3.86
ZHONGYU 5	124	156	98	4.94
SPRLR81047-60-2-2	128	159	105	3.76
CT9497-4-3-1-1-M-4-3P-M	128	160	90	5.01
NANJING 14	121	152	90	5.0
IR55558-50-2-3-3-2	134	174	84	2.34
IR 64	121	152	88	7.89
ZAKHA	121	154	117	3.55

1.1.1.4 Observation Nursery II (IIRON)

It consisted of 120 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 five day-old seedlings were transplanted at a spacing of 20 x 20 cm in the mid-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.

Estimated grain yield (**Table 4**) ranged from 0.84-12.0 t/ha; plant height from 71-131 cm and days to 50% flowering from 101-143. No notable insect pests and diseases were observed among the genotypes. Selected entires will be further assessed.

Table 4 Performance of entries in IIRON 1999

Designation	50% FLW days	Plant Ht cm	Grain yield t/ha
BR5513-38-1-3-2	125	99	10.07
PSB RC-2	128	78	3.90
WAB95-B-B-14-HB	114	103	4.88
IET 13652	115	84	9.31
IR68333-R-R-B-22	114	89	4.92
C15	126	85	7.82
IR 64	121	82	6.32
TOX3098-2-2-1-2-1	142	92	6.77
GIZA 177	103	82	6.03
IR68343-R-R-B-48	114	85	4.69

RP2068-18-4-5	142	100	4.15
IR 72	124	75	5.72
BR(BE)6158-RWBC2-4-4	113	80	7.16
HB 242	134	93	5.26
TOPOLEA 57/77	103	78	4.19
UPR 1329-1-6-1	121	88	7.98
IR 50	114	84	8.64
IR60830-110-3-3-1	121	74	6.33
IR59574-230-3-3	134	93	4.41
RP2233-10-16-9	128	96	7.40
UPR1425-1-4-1	128	84	5.26
ZAKHA	114	123	6.68
CT9496-10-2-1-1-M-1-3P-M-1	121	83	7.24
IR68373-R-R-B-22-2-2	114	81	4.69
IET 13711	121	87	7.71
IR69726-116-1-3	110	89	1.83
IR72	118	77	5.32
B2983B-SR-85-3-2-4	125	118	8.0
91W203	124	86	8.54
9940	134	90	4.23
8360	142	92	5.99
IR64	121	90	11.25
YN883-2	143	122	4.65
IR62164-61-1-3-3-3	124	89	7.01
CNAX4506-3-2-2-1-B	124	96	8.49
UPR1230-9-2	114	96	8.79
IR50	112	96	8.63
IR62037-93-1-3-1-1	112	86	6.52
TOX3116-31-2-3-1	134	80	6.68
IR6510-24-3-6-3-2-3	114	80	6.22
YN1514-50-1	142	90	4.14
PSB RC-2	128	102	3.86
IR46997-69-2-2-2	121	83	8.24
IR64680-81-2-2-1-3	121	90	8.19
12355	121	84	6.70
SPR88090-30-1-2-2	124	98	6.61
ZAKHA	118	85	6.4
ITA406	134	121	4.81
CT7713-26-51-11-41-1-1	124	83	6.44
IR64	121	83	8.13
IR60912-93-3-2-3-3	128	89	5.89
AMAROO	104	84	6.17
YN1851	142	88	2.68
TOX3241-31-2-1-3-1	128	116	6.75
IR50	104	82	6.99
EMPASC 104	121	78	6.47
BTS-24	141	76	2.64
IR62141-114-3-2-2-2	121	88	6.27
H274-27-2-1	105	90	4.14
ZAKHA	115	122	6.98
CT8470-22-13-1-M-4P	128	77	5.14
SPRLR84184-9-5-2-13	128	79	6.34
PNA1010-F4-31-1	134	83	3.85
SPR87036-7-1-1-2	128	108	8.19
IR72	124	72	7.96
D14	115	79	8.56
GUOJING4	124	98	8.50

IR68399-78-2-3-3-1	114	85	3.43
TV2	124	76	6.85
PSB RC-2	134	74	3.06
IR65469-161-2-2-3-2-2	134	88	5.98
HEIBAO	103	64	0.84
UPR82-91	128	87	6.47
UPR1004-30-2-1	115	79	5.21
IR50	114	84	5.92
IR62243-41-1-3-3	121	93	6.83
WAB368-B-8-H1-HB	101	101	2.48
CT6163-8-9-5-2-M-134-M	128	95	4.16
IR65629-2-2-1-3-3-3-1	128	75	4.93
PSB-RC-2	134	75	2.64
TOX3440-47-6-1-1-2	DISCARD	100	-
BR(BE)6157-R1-9	128	106	4.60
MANAW THUKHA	134	99	4.17
IR68997-20-1-2-2-2-	114	88	3.77
IR 64	121	89	7.35
IET13245	114	95	7.94
IR60819-120-3-1	128	90	3.83
IR629075-67-1-2-1-2	128	71	4.55
9925	134	91	2.25
ZAKHA	114	131	6.56
IR68353-35-3-3-2-2-1-2	114	91	5.13
IR63874-113-3-1-3-2	122	78	7.69
IET12884	121	91	12.0
RHS379-25CX-1CX-2CX-02A	134	100	6.52
IR72	124	87	6.45
IR56383-77-1-1	125	90	7.22
RHS351-19CX-7CX-2CX-O2A	124	96	8.02
IR 50	125	88	8.07
PNA403-F4-101-2-1	124	80	3.72
FUJIANG 4	115	93	8.48
WAB176-B-B-25-HB	133	111	4.54
GIZA178	121	90	8.94
IR 72	122	80	6.49
TOX3084-143-1-4-3	128	75	6.89
UPR84-21	121	89	9.29
IR64683-87-2-2-3-3	121	96	6.77
U17	DISCARD	103	-
PSB RC-2	134	79	3.2
LEMONT X DESC/85-6-2-1	121	86	5.10
IR71605-1-1-4-2-3-1-2	121	84	7.91
IR58773-35-3-1-2	134	85	5.44
IR72102-3-115-1-3-2	121	89	8.78
IR 64	121	89	8.46
KARJAT3	128	83	7.79
CNAX4354-5-1-1-3-B	115	91	6.8
CT8837-1-17-1-1-1	134	86	7.18
IR65450-173-2-1-1-3-3	DISCARD	75	-
ZAKHA	115	118	6.43
INIAP 11	128	86	5.93
IR61979-138-1-3-2-2	134	95	6.10

1.1.1.5 Pre-production Evaluation Trial (PRET)

The PRET trials were limited to only three locations due to insufficient seeds. Trials were replicated thrice but crop cuts for yield data could be taken only from two replicates due to damage by animals. Hence no formal analysis was possible. From simple averaging, IR56346-1-1-2-1-9-1-1 gave the highest yield from among the test entries(see Table 5).

Table 5 Average grain yield (t/ha) of rice varieties in on-farm trials

Variety	Zomi	Guma	Bjena	Average
IR 65239-B-B-47-B	6.35	7.94	5.32	6.54
IR 56346-1-1-2-1-9-1-1	6.64	8.41	5.42	8.63
IR 64 (standard check)	5.24	9.11	5.03	6.46
Gyemja/Janam Maap	-	5.32	-	5.32

From farmers' feedback, IR 56346- was reportedly preferred by farmers in Zomi because of its high yield and acceptable straw yield. Guma farmers preferred all the varieties conserving seeds for the next planting season.

1.1.1.6 Evaluation of high-altitude rice lines

Five high-altitude, cold-tolerant and blast resistant rice lines from the Genekha breeding program of RNRRC Yusipang were evaluated in the high elevations of Gasa, Punakha and Wangdue. Data sets have been submitted to RC-Yusipang for analysis and reporting. From the extension feedback it appeared that the quantity of seed which was provided for the trial was not adequate to determine the acceptability of the lines by farmers.

1.1.1.7 Rice double cropping in Wangdue-Punakha valley

Rice double cropping is still continued in Chubu in Punakha. In 2000 there were 39 households practising rice-rice cropping in an area of 79 langdos, average 2.02 langdo per household. Farmers use different rice varieties for double cropping in the valley. Following varieties are commonly used:

First Crop		Second Crop
No.11	-	IR 20913
No.11	-	IR 64
IR 20913	-	IR 20913
Sangay Rinchen	-	IR 64

Majority of the farmers use No.11 followed by IR 20913 and IR 64. Some farmers also use IR 20913 for both the seasons, valuing its early maturity. Although IR20913 does not have great taste and culinary qualities, its rice head recovery during milling is reportedly high. One farmer even tried Chummro as first crop but failed, possibly due to its late maturity (over 160 days). Some farmers also use their local variety, Sangay Rinchen, which has short duration variety as first crop. Although called 'local' by the farmers, this variety is suspected to an improved variety provided for testing by the research centre at some stage. According to farmers Sangay Rinchen has good

yield and taste like IR 64. At Jawakha village (1400 m) most of the farmers grew Sangay Rinchen as first crop but was severely damaged by wild boar, birds and rodents. Majority of farmers in Jawakha are share-croppers of Saula Monastery. Due to severe yield losses double cropping in the future is not likely to be encouraged by the Monastry.

Double cropping of rice is mainly done to supplement food shortages, with hardly any surplus for the market. In terms of grain yield, it does not seem to be higher than a single normal crop (approx 40-45 drey/langdo as per farmers' estimates). There seems no rigid categorisation of farmers who do rice double cropping; some farmers even if poor don't grow two rice crops, and even some rich farmers do grow two crops. Farmers experiment with different varieties because No.11 is hard to thresh and taste is not good. Some also said No.11 creates heart problem/pain. A decline in rice double cropping acreage is not attributable to technology failure, but due to other factors such as share-cropping, damage by wildboars, birds and rodents, labour and irrigation scarcity etc.

1.1.1.8 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 6.

Table 6 Rice seed maintenance and production, 1999.

Variety	Quantity (Kg)	Nucleus Seed
IR 20913	240	286
IR 64	830	174
Barket	52	-
Chumro	70	-
Bajo Maap 1	1200	200
Bajo Kaap 1	648	333
Bajo Maap 2	1000	200
Bajo Kaap 2	337	200
IR 65239-B-B-47-B	180	200
IR 62467-B-R-B-B-1-1-B	180	-
PP2(23-1)	40	-
PP3-31(2-1)	50	-
PP3-22(3-1)	40	-
PP2(8-5)	40	-
PP22(1-2)	50	-
PP2(31-4)	30	-
PP2(31-1)	30	-
PP2(23-3)	20	-
Paro China	34	-

1.1.1.9 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 1999 a total of 111 local rice varieties from different altitudes were rejuvenated and characterised at the station (Appendix 1).

1.1.2 Grain Legumes

1.1.2.1 Mungbean Variety Trial

Mungbean is popular only in southern and eastern part of the country. Nevertheless because of high market price and fertility enhancing capacity, the centre is evaluating and selecting varieties for wider promotion. From last year's selection, 11 varieties were further evaluated with local variety as check.

The trial was conducted in RCBD with 3 reps, in plot size of 2m X 2m with spacing of 30-cm row to row and 5-10cm plant to plant. Fertilizer was applied at the rate of 40:40:40 NPK kg/ha as basal dose. Seeds were sown in the 3rd week of August and harvested in the last week of October. A light weeding and thinning was given after 30 days of sowing. The crop was raised in rain-fed condition. Since the crop was sown in wetland, irrigation channel around the trial was made to drain the excess rainwater, which otherwise will create water logging. The yield is presented in the Table 7. There was not much infection by powdery mildew. All the improved varieties matured 12 days before local variety and 4 of the VC lines gave higher yield than the local, though the yield difference was not significant.

Table 7 Grain yield (t/ha) of mungbean varieties

Variety	Grain yield
VC6173 B-13	0.790
VC6173 B-33	0.707
VC6141-90	0.730
VC6173 B-10	0.830
VC6173 B-6	1.257
VC6368(46-40-4)	1.097
VC3960-89	1.163
VC6173 B-14	0.867
VC6369(53-97)	0.863
VC6379(23-11)	0.907
VC6375(14-13-6)	1.263
Local (check)	0.980
CV%	31.8
S.E.D	0.247

It has been observed that the improved varieties were more sensitive to water logging. But with the advantage of early maturity, taste and yield, the improved varieties are likely to be adopted by the farmers.

1.2 Crop Production Management

1.2.1 Yield optimisation trial in rice

Rice farming in Bhutan is basically of subsistence nature. There are hardly any commercial rice farmers who sell their produce in bulk in the local markets. As a preferred staple, over 30% of our requirement is met through imports; one of the cherished goals of the RGOB is to produce more rice domestically so as to raise our self-sufficiency level. One of the ways to raise rice productivity and hence production is to apply additional fertilisers, as the current rate of use is almost insignificant. The present trial was thus designed to explore the optimum/maximum yield potential of rice using a combination of fertilisers and improved rice varieties.

The trial was set up as a factorial RCBD, with 6 improved varieties (see Table) and 2 levels of fertility:

Level 1: 80:40:20 NPK kg/ha + FYM 20t/ha.
Level 2: 120:80:30 NPK Kg/ha + FYM 10 t/ha.

There were 3 replications with a plot size of 4m x 3.5 m and a spacing of 20cm x 20 cm. One month old seedlings were transplanted in rows in the third week of June. Butachlor 5 G @ 2kg a.i/ha was applied after 3 days of transplanting. Fertilizer was applied in 3 splits – basally, at tillering and at flowering stages. Recommended management practices were followed.

Table 8 Effect of different fertility levels on the grain and straw yield of 6 rice varieties

	Grain Yield (t/ha)			Straw Yield (t/ha)		
Variety	*L1*	*L2*	*Mean*	*L1*	*L2*	*Mean*
IR 64	9.33	10.87	10.10	6.89	8.76	7.83
M 54	8.24	8.58	8.41	8.83	9.17	9.00
BM-1	8.91	9.95	9.43	5.06	9.83	7.44
BM-2	7.24	8.16	7.70	7.66	7.38	7.52
BK-1	9.61	10.77	10.19	6.11	7.89	7.00
BK-2	9.61	11.34	10.48	7.50	7.89	7.70
Mean	8.82	9.95	9.39	7.00	8.49	7.75
	F variety	**		F variety	*	
	F fertility level	**		F fertility level	ns	
	F var x f-level	ns		F var x f-level	ns	
	SED var	0.48		SED var	0.86	
	SED f-level	0.28		SED f-level	0.49	
	CV %	8.8		CV %	19.3	

L1 = 80:40:20 NPK kg/ha + 20 t FYM/ha; L2 = 120:80:30 NPK kg/ha + 10 t FYM/ha
BM = Bajo Maap; BK = Bajo Kaap varieties

ANOVA was used to detect treatment differences using Genstat 4.1. Results are presented in Table 8. There were significant (P<0.01) variety and fertility level effects, but the variety x fertility level interactions were insignificant. Of the two fertility levels L2, which is almost doubling of the NPK, produced an average 1.13 t/ha more grains

than L1, reflecting an overall response of the improved varieties to additional fertilisation. Averaged across fertility levels, variety BK-2 yielded the highest at 10.48 t/ha, a 4% increase from the popular variety IR64. BK-2 also showed the maximum responsiveness to higher fertilisation. Straw yields were measured after sun drying, hence the figures are lower than those of grains. Only the variety effect was significant with regard to straw yield.

The above results suggest that rice yields could substantially be increased using a higher dose of NPK in the presence of adequate organic materials such as FYM.

1.2.2 Effective Micro-Organism (EM)

EM activities were started in 1995. Since then a demonstration plot on Nature Farming has been established to evaluate as well as demonstrate the merits of organic agriculture and the value-addition of EM.

Nature Farming using EM technology

The major objective of nature farming using EM technology is to improve the productivity and efficiency of resources use, with the least detriment to the natural environment on which the production is based. It is a farming method without the use of synthetic agrochemicals.

The Nature Farm roughly measures 4000 sqm. It is intended as a long-term study in a rice-based system. Crops included are rice followed by wheat or mustard. Maize is also grown under upland conditions. Grain legumes are grown on rice bunds and fruit and forest trees are planted at the fringes of the terraces.

For all crops inorganic fertilizer and pesticides are not applied. All crop residues are incorporated into the soil along with 5 t/ha of FYM and 7 t/ha of Bokashi at the time of land preparation. EM solution prepared at the ratio of 1:1:100 (EM, molasses, and water) is sprayed. Other management practices are followed as per normal practice for each individual crop. EM5 is sprayed twice a week if there is any pest or disease problem.

Table 9 Cropping calendar and varieties grown in 1999-2000.

Crop	Variety	Date sown/planted	Harvest date	Remarks
Rice	IR 64	3rd wk June	3rd wk Oct	
Wheat	BK 2	3wk Nov	2nd wk May	
Mustard	M-27	3rd wk Nov	2nd wk Apr	
Maize	Yangtsipa	4th wk May	3rd wk Aug	
Pear	Local	1995	2000 fruiting started	
Banana	Improved	1995	-	fruiting not started
	Local	2000	-	
Guava	Local	2000	-	
Tree tomato	Local	1999	2000 fruiting started	

For fruit and forest trees EM bokashi and FYM is applied twice a year around the basin. EM solution is also sprayed at the foliage. Forest tree species include *Melia azedarach, Eriolobus indica* and *Ficus religiousa.* Crop yields from 1995-2000 are presented in the table below.

Table 10 Grain yield (t/ha) of various crops from 1995-2000.

Crop	YEAR				
	95-96	96-97	97-98	98-99	99-00
Rice	8.70	4.40	5.05	6.26	6.50
Wheat	0.77	1.25	1.05	1.20	1.90
Mustard	0.26	0.27	0.41	0.49	0.49
Maize	6.37	5.82	6.84	7.70	5.00

The yields as presented in the table and figure above are good and comparable to those where agro-chemicals may have been used. Yield of rice for the first year was high because the field was under green manure (*Sesbania aculeata*) for more than 3 years which increased rice yield. From the following year the yield dipped down and has gradually stabilised at about 6 t/ha. The yield for wheat for 1999-00 was good (1.9t/ha) and on the rise. The yield of maize has decreased as compared to the last year because of the change in plot. The new plot will take some time to improve soil fertility.

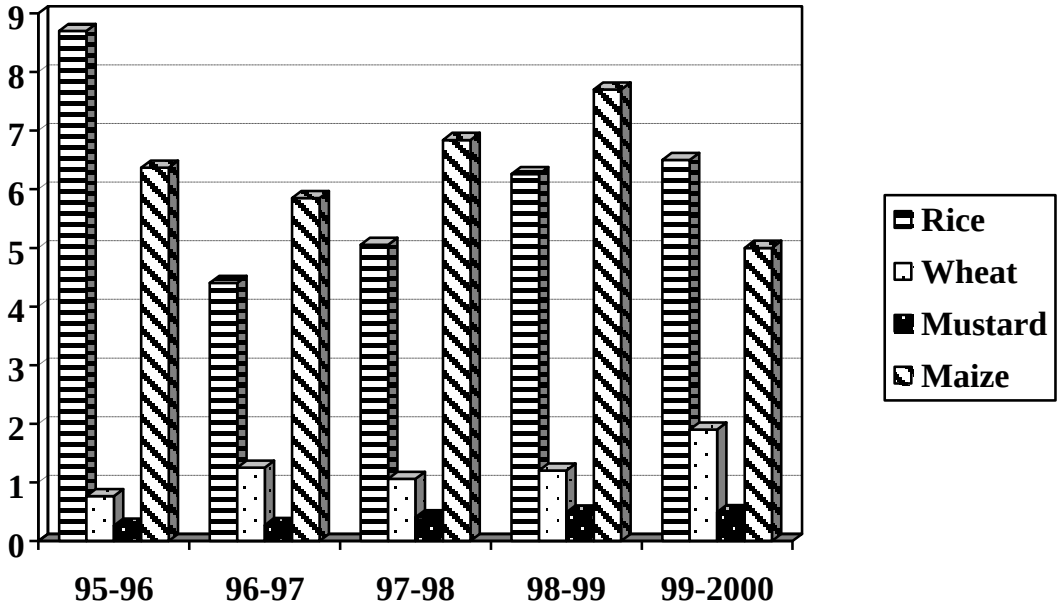


Figure 1 Crop yields (t/ha) from 1995-2000

As Nature Farming involves long-term investment, it does take time to improve soil texture, weed management and fertility of the soil. Data on the number of weeding and the time taken to weed rice show that it takes a number of of years to suppress weed population. For winter crops it is much easier to manage. Unlike rice there is no weed problem and if the soil moisture is adequate, which is important for establishment, yields are generally high.

Soil analyses in the beginning and in between are also done. Besides yield, pest and diseases problems are also monitored and recorded. Nature Farming uses only organic matter, which favours insects and pests, both beneficial and harmful. The most common is mole cricket. It is believed to be beneficial since it helps in soil aeration but it also creates problems since it makes tunnels in rice bunds, draining out irrigation water. This calls for extra work to plaster bunds and seal off the escape holes.

Agriculture in Bhutan is basically organic. The six-year experience tells us that we can encourage organic farming. Provided that optimum organic matters are available and used, crop yields comparable to using chemical fertilizers can be obtained However, production economics will largely influence the acceptability of this method.

2 HORTICULTURE

2.1 Subtropical Fruits

2.1.1 Introduction

The period July 99 to June 2000 was one in which fruits research saw gradual progress in previousely-initiated work viz. varietal evaluation and propagation programme. Evaluation of the existing germplasm, both on-station and on-farm, continued with renewed vigour. Efforts also continued in sourcing, introducing and establishing new germplasm to increase the number of collections for evaluation. The season also saw the introduction of five new cultivars of mandarin through the auspices of the Citrus Improvement Project of the JG.AG Foundation. The new mandarin cultivars came in the form of bud-woods and are being propagated further to obtain sufficient quantity for establishing an adaptability trial of their own.
In addition to the result reported in the last report, result has been generated on pecan evaluation also. Steady progress was seen in improving the research facilities. The propagation programme benifited immensely by constructing a plastic house, in terms of being able to extend the period of budding process. Irrigation has been also improved with the construction of the second pump leading to fruits research site.

2.1.2 Integrated germplasm collection and development

2.1.2.1 Varietal evaluation of pecan cultivars

Pecan is a sub-tropical fruit whose cultivation in Bhutan is limited to a few trees in a few backyards across the country. These few trees are old trees which have been probably introduced from India. Indigenous pecan plants are not found even in the wild in the country. It has a huge potential for cultivation in the country in that it is similar to walnut in properties but has added advantage of being sub-tropical in habitat and has softer shells than walnut.
This trial was conducted with the objective to evaluate adaptability and performance of different improved cultivars of pecan. Four cultivars of pecan with five plants each were planted in the trial orchard in 1994 at a spacing of 7mx7m row to row and plant to plant. The parameters considered for evaluation were tree growth, bearing habits and fruit qualities. All recommended management practices were carried out annually during the season. The trees are into seventh year growth and the first harvest was reaped in the seventh year this September.

Cultivar	No of fruits	Fruit dia (cm)	Fruit length (cm)	Harvest time	Av. trunk size (cm)
Nellis	8	2.5	3.9	28.9.2000	58
Western Schley	257	2.1	3.5	28.9.2000	52
Mahan	184	2.0	3.1	28.9.2000	57
Burkett	88	2.1	3.4	28.9.2000	63

The overall performance of the trees look very encouraging, with good tree canopy, trunk and reasonably good first year fruiting. Of the four cultivars yield was highest

with Western Schley followed by Mahan. In fruit size there was not much difference with average fruit diameter of 2.1cm and length of 3.4cm. Tree trunks also were of similar size. Harvest was done at the same time for all the cultivars. Further observation needs to be carried out in the next two seasons to determine the ultimate promises of this crop.

2.1.2.2 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, colour, juiciness and taste. The trial is completed by this year asthe trees have come to into full bearing. Of the citrus collection these have reached sixth-year bearing and results are presented below.

Table-3: Yield and other fruit traits of citrus cultivars

Variety	Shape	Fruit colour	Juice content	Seediness	Harvest time	Yield (No of trees)	TSS %
Ichifumi	Flat	Yellow	Juicy	Seedless	Late Sept	52	12-13
Miyagawa	Round	Yellow	Juicy	Seedless	October	37	-
Okitsu wase	Round	Yellow	Juicy	Seedless	Early Oct	85	8-9
Matshuda	Similar to local	Yellow	Juicy	Less seed	Mid Nov	18	-
Oota ponkan	Similar to local	Yellow	Juicy	Seeded	Late Dec	115	9-10
Encore	Flat	Yellow	Juicy	Seeded	Jan	163	10-11
Seminole	Round	Yellow	Juicy	Seeded	Jan-Feb	140	8-10
Lyo	Round	Yellow	Juicy	Seeded	Dec-Jan	10	7-8
M. Lyo	Round	Yellow	Juicy	Seeded	Nov-Dec	41	8-9
Freemont	Similar to local	Orange	Juicy	Moderate	Nov-Dec	57	13-14
Clementine	Round	Orange	Juicy	Less seed	Nov-Dec	69	12-13
Bears	Egg	Yellow	Juicy	Seedless	Nov-Dec	123	-
Limoniera	Egg	Green	Juicy	Seeded	Dec.	42	-
Lane late	Round	Orange	Juicy	Less seed	Dec.	9	-

Of the three cultivars of satsuma mandarins Ichifumi Wase matures 7-10 days earlier than the other satsuma cultivars Okitsu wase and Miyagawa wase. The first harvest of Miyagawa was done in October this year and is sweeter than Ichifumi, though Ichifumi has been reported the most sweet among the satsumas in the last report. Okitsu wase on the other hand has firm fruits. Oota Ponkan(normal mandarin) is similar to our local mandarin but matures about a week early. Seminole is highly acidic and juicy. Sample testing for juice extraction sent to Agro Industries, Wangchutaba has reported that Seminole has a potential for future juice production. Miyuachi-Iyo and Iyo are both tangors (hybrids of tangerine and sweet orange), which bear 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. All the

lime/ lemon cultivars have good fruit qualities and are superior to the existing local lime/ lemon.
Based on this year's result Ichifumi, Okitsu, Oota Ponkan, Miyagawa wase, Minneola, Miyauchi Iyo, Freemont, Clementine, Valencia, Bearss, Meyer and Limoniera are being tested in the farmers' field at different agro-ecological zones for further tests of preference and acceptability.

2.1.2.3 Varietal evaluation of cardamom:

In the past, cardamom cultivars were planted by the farmers without due consideration being given to their suitability to various egro-ecological factors, resulting in poor growth and yield and in most cases severe incidence of wilt disease. Thus, a need was felt to carry out a study to develop a database on cardamom husbandry as done under Bhutanese conditions, to study the suitability, productivity and pest/disease tolerance of different cultivars across different agro-ecological zones and develop recommendations based on long term observation. A collaborative trial, coordinated by RNRRC Bjakar, is underway with four cultivars- Bharlanghe, Dzongu Golsey, Ramsey and Sawney, of large cardamom purchased from Sibsoo dungkhag and planted in lower Tshokhana geog, Tsirang. The trial design is RCBD with 3 replicates per cultivar, planted at a spacing of 1.5x1.5m with two pseudostems in each pit. Monitoring and data collection shall start from coming spring.

2.1.3 Propagation Trials

2.1.3.1 Persimmon budding

Most of the existing persimmon plant in the country are either traditional Bhutanese cultivars or Indian cultivars which are of the stringent type, which has limitations in marketing. A trial has been initiated in an orchard at Nobgang, Punakha last summer to bud the astringent Japanese cultivar onto young plants of Indian cultivars. The objective of the trial was to find out the possibility of top-working established young plants of Indian persimmon with Japanese cutlivar through summer budding. Two methods of budding – chip and T-budding, were carried out. In total 15 buds were budded, out of which 2 buds did not take. An important observation was made in the first lot of budding in the timing of plastic removal. Unlike in budding other fruit crops where budding plastic is removed in the fourth week after budding, in persimmon plastic removal should be delayed till spring. It was observed that the persimmon bud tends to take longer duration to take. Final bud take can be deduced only in the coming spring.

2.1.3.2 Lime top-working

The growers in growing lime plants both at the backyard and plantation scale show-increasing interest. A trial was initiated at Shengana, Punakha June this season to top-work established Assam lemon plants with improved lime cultivar- Bearss., with the objective of ascertaining the possibility of top-working lime on lemon and explore future scope of scaling up this activity. A total of 45 lemon plants were de-topped and budded with buds of Bearss using T-budding technique. Bud take success has been

90% and so far the buds are in good condition. Plastic has been removed four weeks after budding. It remains to see how the buds shoot out in the coming spring.

2.1.3.3 Top-working of apricot cultivar on plum rootstock

Till now in the history of plant propagation in Bhutan, the most commonly used rootstock for the stone fruits have been the seedlings of the local peach (small peach). More recently there has been an effort to use the improved almond-peach hybrid called GF677, however its use is constrained by its difficulty in propagation. This activity was initiated to explore the possibility of using plum as both a rootstock as well as an interstock for budding apricot. 15 six-year-old plum trees were top-worked with two cultivars of apricot in March 2000. The percentage graft success was about 80 %, which was more than expected.

2.1.4 Production Management

2.1.4.1 Compatibility trial of local mandarin cultivars with four improved rootstocks

Traditionally, and even now, the method of propagation of the local mandarin is done through seeds, which has many disadvantages among which the variation of the seedlings, extended period of juvenility and uncontrolled vigor of the plants result in future management and economic constraints. The suppliers of planting materials and the growers do still not practice the standard vegetative method of propagation. In order to encourage planting vegetatively propagated materials it was felt necessary to find the best rootstock suitable to the local mandarin. This trial was thus initiated with the objective to determine the best rootstock for the local mandarin. However, the trial is still in its initials phase of multiplying sufficient materials for planting. A few trees on three different rootstocks have been planted for initial observation, which are growing well. The trial will be properly designed and conducted in the coming year.

2.1.5 On-farm

This season has seen increased momentum in the sector's drive to push every tested and promising materials into on-farm trials. Three demonstration orchards, housing all the promising cultivars of different sub-tropical fruits have been established, and evaluation of sub-tropical fruit trees under farmers' management level continues vigorously. Eight additional demo orchards are in the pipeline, expecting establishment in the coming season. Apart from the demo orchards a cardamom varietal evaluation has been also established in Tsirang in collaboration with RNRRC Bjakar.

2.1.6 Germplasm introduction during the year

Crop/Variety	Source
Cardamom	RNRRC Bjakar (Sibsoo)
Bharlange	
Dzongu Golsey	
Ramsey	
Swaney	
Mandarin	JG.AG (INRA, France)
Kinnow	
Fortuna	
Washington	
Sunburst	
Nova	

2.2 Vegetable research

2.2.1 Asparagus Varietal Evaluation

Nine hybrid asparagus varieties were sown in the nursery in April 1994 and transplanted in July 1995. The trial was established to evaluate these nine hybrid varieties for yield, earliness in production and spear quality. The trial was laid out in a randomised complete block design with four replications. The plot size is 7 x 1 m^2. First harvest began in 1997 and thereafter-yearly harvest data were collected to assess the yielding ability of these varieties.
There is a gradual increase in yield over the years in all the varieties. High yield (8-9 t/ha) was observed in varieties Carlim, FIUC, Gijlim and Thelim. The other varieties did not do yield very well in comparison to these varieties. The lowest yielder was Larak and De Argentinal with a total yield of about 6t/ha.

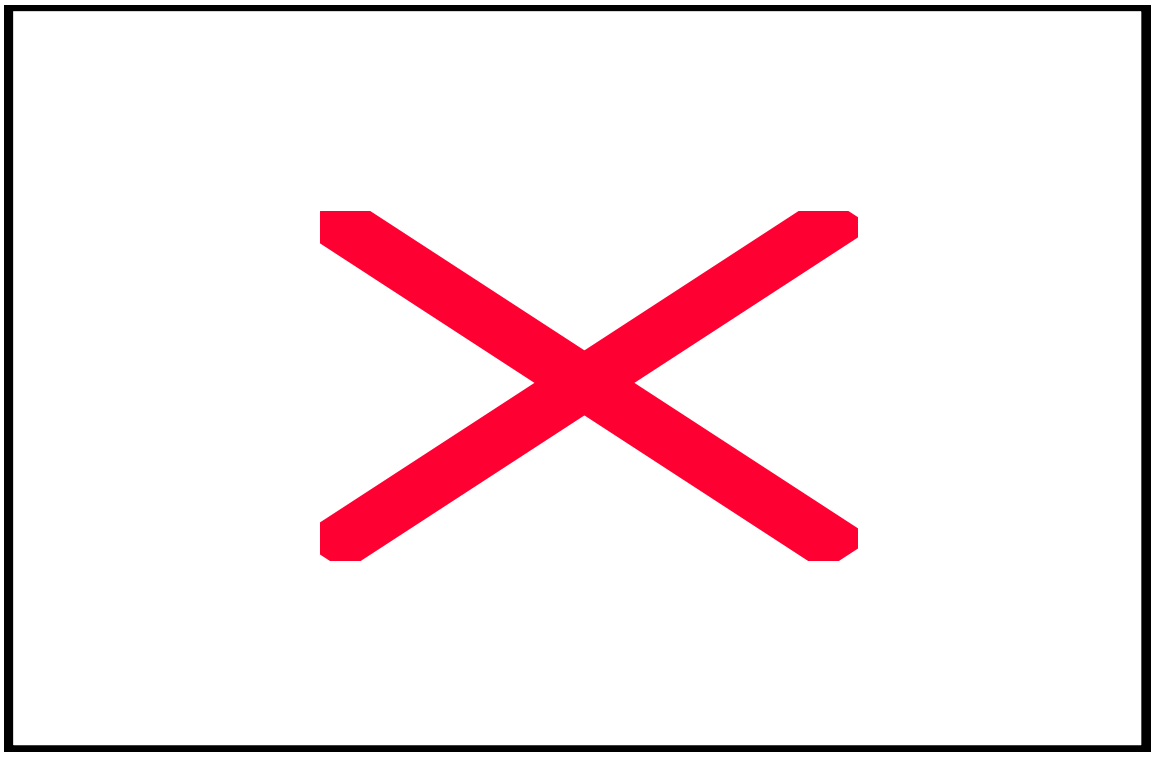


Figure 2. Total yield of 9 asparagus varieties, 1997-2000.

2.2.2 Okra Varietal Evaluation

The main objective of the trial was to evaluate better performing varieties of okra from different countries for yield, disease/pest reaction, tenderness of fruit and other important characteristics.

The trial was laid out in a RCBD with four replications. 4 new varieties (Arka Anamika, MI 5, Harita, Banana Smith) were tested along with a local check Blue Bell. The seeds were sown on 17.8.99

The plot size was 5 sqm. (1 x 5 m each per variety) with 50 cm row to row X 50 cm plant to plant spacing. Recommended fertilisation 40:60:20 NPK kg/ha and other cultural practices were followed. 20 kg N was basal, 20 kg was top dressed 45 days after planting.
The major horticultural characteristics measured were days to first fruit harvest, fruit length (cm), fruit girth (cm), no. of fruits per plot, yield per plot, no. of ridges per fruit, plant height and diseases and pests

Table 11. Characteristics of five okra varieties tested.

Variety	Yield (t/ha)	Plant height (cm)	No. of ridges/fruit	Fruit length (cm)	Fruit girth (cm)
Arka Anamika	7.79	81.15	5.37	19.9	10.1
Banana Smith	3.05	43.65	3.5	11.2	4.8
Bluebell (ck)	5.46	91.62	5.82	19.0	11.5
Harita	4.21	61.73	4.47	15.4	8.6
MI 5	4.71	69.3	4.15	14.7	8.1
LSD (0.05)	4.98	69.02	4.5	15.4	7.79
CV%	25.7	19.1	6.6	6.2	5.4

Arka Anamika produced the highest yield and was early maturing. There were no significant differences in the yield of the other varieties. Bluebell, the check variety was the tallest plant. Good fruit qualities were observed in Arka Anamika having long, lush, green and smooth tender fruits with 5-6 ridges. No incidence of disease and pests were observed during the course of the trial. Arka Anamika will be further tested for adaptability in various locations in the next season.

2.2.3 Onion Varietal Observation

Onion is among the major vegetable crops grown and consumed all over the world. It is also the most versatile crops and can easily fit into various cropping systems and allow efficient use of resources.
The growers desire varieties that are suitable for growing after harvesting the rice crop and that store well.
This trial will evaluate various varieties received from AVRDC and SAVERNET along with the local check Bombay red for yield, bulb quality and storability.

The varieties, AC 893 (Arka Kalyan), AC 464 (Arka Niketan), AC 740 (Explorer), AC 47, AC 11, AC 2, TG 50, AC 745, and Bombay red (check) were tested in single plots as observations. The management practices were followed as per recommendations. The plot size 1 m x 1.5 m (1.5 m^2) at a spacing of 10 cm PP and 15 cm RR. The seeds were sown in seed sowing flats in October 1999 and transplanted in the field in December. Harvesting of the bulbs were done when all the tops had turned brown and wilted. Harvesting was carried out in the end of May.

Table 12. Yield and bulb characteristics of 8 onion cultivars.

Variety	Nos/ plot	Yield t/ha	Bulb length (cm)	Bulb width (cm)	Bulb weight (g)	Colour
Arka Niketan	22	10.00	43.5	59.4	91.7	red
AC47	27	10.00	45.2	57.3	108	red
AC11	13	3.33	28	50.3	60	red
AC2	16	4.00	39.7	46.3	50	red
TG50	23	14.67	68	75.8	150	yellow
AC745	14	26.00	59.2	53.8	77.6	red
Bombay red (ck)	21	8.67	42	57.5	91.6	red
Explorer	28	26.67	50.9	67.1	175	yellow

The results show that the highest yield was produced by the entry AC745 (26 t/ha). TG50, a Texas Grano type yielded fairly high (14 t/ha). Followed by Arka Niketan and AC47. Explorer, TG50 and AC47 produced big wide bulbs. Arka Niketan from India produced the desirable sized bulbs with red colour. It yielded higher than the local check Bombay red. This variety was also found to be preferred by most farmers due to its characteristics and marketability. The storage tests are still on going so the results are not yet available. Further storage tests will reveal the most desirable varieties for promotion.

2.2.4 Radish 45 Days Variety

Radish is an important traditional vegetable grown thourghout the country. It plays an important role in the traditional diet of the people. It is either eaten raw or cooked with meat or cheese. The tops are dried and eaten as a delicacy with PA.
The varieties available for general cultivation are either suitable only for early spring or winter production. The root quality and uniformity, hairiness of the leaves, pungency of the roots are some of the important characteristics of evaluating radish varieties. Early maturing is an added advantage to maximise the cropping intensities.
The seeds of the variety Hongkong white were made available through the Regional farm DSC Bajo. For the summer crop, the seeds were sown in the field on 10 June 2000, germination was observed in three days. The roots were ready for harvest by the 26th of July, in about 45 days after sowing. For the autumn crop, sowing was done on 26th July and harvested on 11th September.

Table 13. Characteristics of radish variety Hongkong white

Characteristics	Summer crop	Autumn crop
Plant canopy (cm)	40 x 40	50 x 45
Plant height (cm)	50.17	59
Root length (cm)	29.53	34.67
Root dia (cm)	4.6	5.79
Yield (t/ha)	102.60	75.0
Root colour	Clean white (Very less hair/ roots)	
Leaf colour	Light green (Smooth and hairless)	

This variety is not hairy, both the tops and roots can be eaten either raw or cooked. The roots are clean and white. Tasting exercise brought out several feedback. Most found that the variety was easily cooked than the local ones. The cooked tasted as good as the local radishes. However, when eaten raw, most people found that it was too pungent. Some suggested it as suitable for pickling.

2.2.5 Potato CVT for Low and Mid Altitudes

The trial was conducted to screen lines for early maturity and tuber yield and characteristics for potato production in the low and mid altitude regions. The main emphasis was given to short duration lines that would mature earlier than the local check Desiree.
The seeds were obtained from RNRRC Yusipang and planted in the field on 27th Jan 2000. The trial was laid out in a RCBD with three replications. The plot sizes were 2.4m x 3 m, each containing 4 rows and 12 tubers per row. Fertilizer was applied at the recommended rate of 100:80:30 N:P:K kg/ha, whole P, K and 80 Kg N applied at planting. Remaining N was top dressed 45 days after planting. The harvesting of two entries were carried out in the end of May and the rest were harvested by the end of June. Although the foliage were still green and flowering, harvesting was done with the view that rice transplanting time was over.

Table 14 Yield and other characteristics of 6 new potato lines.

Variety	Emergence per plot (30 DAP)	Avg no of stem /plot	Days to maturity	Yield (t/ha)			
				Small size	Seed size	Large size	Total
386031.1	11.3	3.63	149	3.04	5.00	1.77	9.8
386036.7	10.7	2.47	149	2.35	3.53	1.37	7.25
343191.1	10	3.07	149	1.77	3.24	1.96	6.96
385006.6	15.7	5.10	149	2.56	3.18	1.86	7.31
676079	4	2.53	116	3.53	2.65	1.32	7.5
Desiree	7	2.00	116	2.55	3.92	2.06	8.53
SED	5.34	0.39		0.51	0.97	1.13	1.24
CV%	66.9	15.3		24.1	33.2	80.8	19.3

There were no incidences of late blight but the whole plot was affected by Early Blight which brought a reduction in the total yield of all the entries tested. Dithane M45 was sprayed three times at an interval of 15 days.
Statistically, none of the test entries outyielded the local check Desiree. Entry 676079 and Desiree matured at the same time while the rest of the entries matured about a month late. Tuber size and quality was best in the local check. However, the entry 676079 could be tried in different locations in farmer's fields for further observations since it was found to be early maturing.

2.2.6 Effect of Spacing and Nitrogen on the Bulb Quality and Yield of Onion

Onion is among the major vegetable crops grown and consumed all over the world. It is among the most versatile crops and can easily fit into various cropping systems and allow efficient use of resources.

Splitting of bulbs is one serious limiting factor in commercial onion bulb production. It is attributed to the luxuriant growing environment in the field during bulb formation phase. Excessive nitrogen and wider spacing are believed to cause splitting.

This trial was conducted to study the response to nitrogen and spacing treatments of the popular local variety, Bombay Red, in terms of yield, bulb splitting (or doubling), and other traits. The trial was laid out in a 2 x 2 factorial in RCBD with three replications.

The treatments were as follows:

2 Nitrogen levels : N1- 0 N
N2- 70 kg N/ha (apply in splits at three different stages, one-half at transplanting, other half as top dressing 30 DAP and 45 DAP)

Spacing S1- 15 x 15 cm
S2- 20 x 15 cm

The seeds were sown in October and transplanted in mid December. The bulbs were harvested in the end of May when all the foliage has turned brown and wilted on the ground. All the recommended cultural practices were followed.

Table 15. Mean yield, mean bulb weight and % bulb splitting of onion at two nitrogen levels and spacing.

Nitrogen level	Spacing		Mean
	15 x 15 cm	20 x 15 cm	
Mean yield (t/ha)			
0 N	23.0	13.5	18.2
70 kg N	21.5a	14.7 b	18.1
Mean	22.2a	14.1 b	18.2
CV%=12.3 %			
Mean bulb weight (g)			
0 N	122.4	145.8	134.1
70 kg N	113.5	145.7	129.6
Mean	117.0 b	145.7 a	131.8
CV%= 11.8%			
% bulb splitting			
0 N	48.7	60.0	54.4
70 kg N	27.4	67.1	47.2
Mean	38.1 b	63.6 a	50.8
CV%= 32.2%			

Application of nitrogen did not have any significant effect on yield and other bulb characters while spacing had a consistently significant effect on yield, bulb size and splitting. A closer spacing of 15 x 15 cm produced a higher yield and less percentage of split bulbs.

Higher plant population in closer spacing contributed to higher yield while wider spacing resulted in low plant population and consequently low yield although the bulb size was bigger.

Onion bulbs grew bigger when ample space was provided at planting. At the same time, bulb-splitting tendency increased, as the bulbs grew bigger. Therefore, it is

advisable to maintain a bulb spacing of 15 x 15 cm or even 10 x 15 cm for a uniform and sizeable bulb.

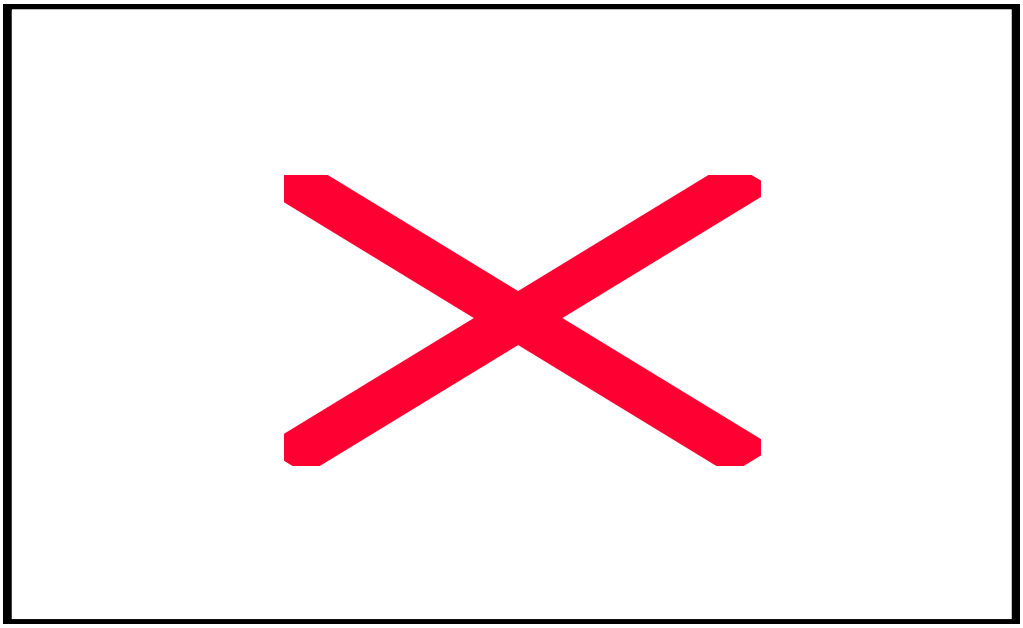


Figure 3. Effect of nitrogen and spacing on the bulb splitting in onion

2.2.7 Effect of Spacing & Fertilizer Application Method on the Tuber Size, Quality and Yield

Literature recommends that the fertilizer application procedure for potato cultivation be side dressing. However, our farmers practice broadcasting and mostly place the fertilizers in the furrows and place the seed potatoes directly on top. The recommended spacing between plants is 25 cm. This spacing is recommended for general production. For seed production, a spacing of 10-15 cm is desired.
This trial was to study the response to fertilizer application method and spacing on the yield and tuber quality, shape and size of the popular local variety, Desiree.

The trial design used was 3 x 3 factorial in RCBD with three replications. The treatments were as follows:

1. Fertilizer application methods
F1 Farmers method; furrow placement (high altd)
F2 Broadcasting (rice based)
F3 Side dressing

2. Spacing (PxP)
S1 25 cm
S2 15 cm
S3 10 cm

Seeds were sown on 19th Jan 2000. All necessary recommendation was followed.

Table 16 Response of potato to different fertilizer application methods and spacing.

Treatment	Treatment structure	Emergence	Average no of stems	Large (t/ha)	Seed (t/ha)	Small (t/ha)	Total yield (t/ha)
1	F1S1	3.67	1.6	3.29	5.79	2.64	11.71
2	F1S2	12.67	2.16	2.5	6.96	2.94	12.4
3	F1S3	10.67	2.54	1.88	4.72	4.27	10.87
4	F2S1	9.67	1.73	2.25	4.86	1.76	8.86
5	F2S2	14	1.8	2.66	6.34	3.12	12.1
6	F2S3	19.67	2.6	2.43	5.86	4.68	12.95
7	F3S1	8.67	1.87	2.71	5.07	3.17	10.94
8	F3S2	9.33	2.14	3.88	5.05	3.54	12.47
9	F3S3	14.67	2.46	1.83	6.89	4.38	13.1
CV%		41.3	24.7	53	24.7	28.2	18.3
LSD		4.7	0.51	1.39	1.41	0.95	2.13

There is no statistically significant effect of the method of fertilizer application on the yield. Fertilizer application methods such as furrow placement, broadcasting and side dressing were found to be equally good. Seed spacing showed a significant effect on the total yield. Wider seed spacing within a row gave lower yield. There was a significant effect of the interaction of the two treatments. Generally, lower yield was observed if a spacing of 25 cm seed to seed was used. Yield was almost the same in all the treatments is a spacing of 15 cm was used. Total yield increased in a spacing of 10 cm for those plots which were broadcasted and sidedressed. In closer planted plots, yield decreased if fertilizer was applied in furrows.

It is therefore recommended that if potato growers are following a seed spacing of 10cm seed to seed, fertilizer application can be done by broadcasting or side dressing. Applying the fertilizer in the furrows decreased yield if a seed to seed spacing of 10 cm is used. However, side dressing was found to be the most suitable method of fertilizer application if the seed to seed spacing was maintained at 15-25 cm. Generally, closer the seed to seed spacing, higher the yield but a spacing of 15 cm was found to be the most optimum for any type of fertilizer application method.

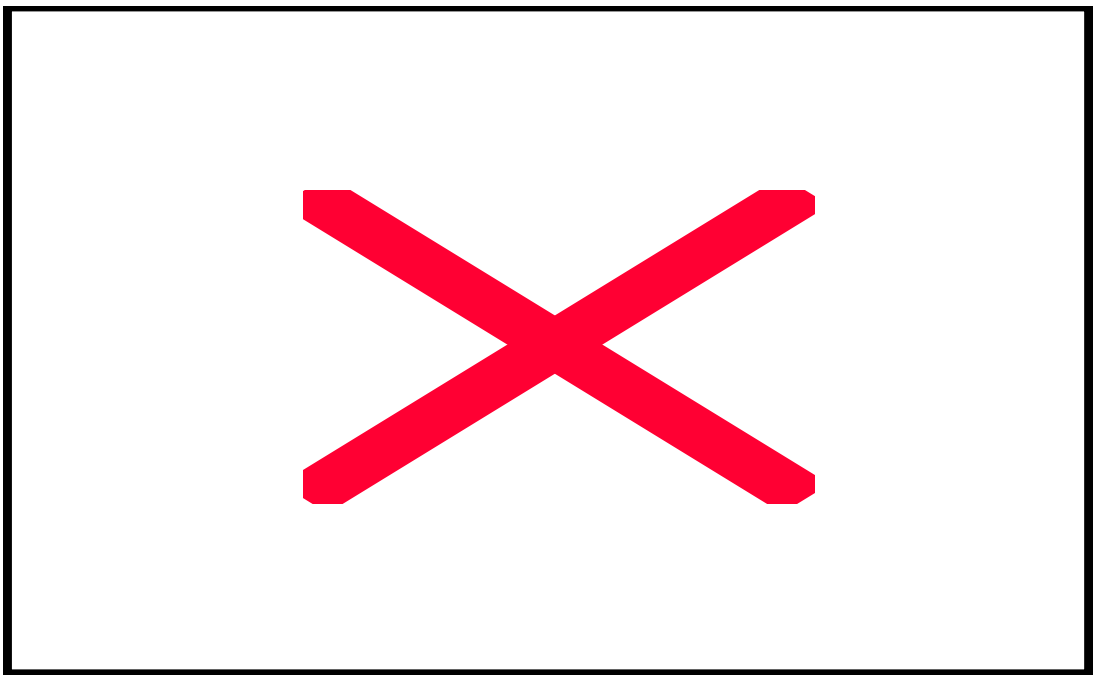


Figure 4. Effect of spacing and fertilizer application method on potato yield

2.2.8 Potato onfarm high altitude varietal

The trial was conducted to evaluate the performance and disease resistance of three new potato varieties under farmer's management in the high altitude areas in comparison to the local check variety.

The seeds were obtained from RNRRC Yusipang and planted in the field on 10th April 2000. A farmer from Gaselo Geog, village Tapchakha was selected for the trial. The trial was laid out in a RCBD with three replications. The plot sizes were 2.4m x 3 m, each containing 4 rows and 12 tubers per row. Fertilizer application was only in the form of farmyard manure. A total of three weedings and three earthing up were done by the farmer.

The harvesting was done on 7th July 2000. All the new varieties were harvested at the same time except the local variety, which was harvested two week earlier. Although the foliage were still green and flowering, harvesting was done with the view that rice transplanting time was over.

Table 17. Yield of new potato lines tested in farmers fields

	Tubers/plot			Tuber yield (t/ha)			
Variety	Small	Seed	Large	Small	Seed	Large	Total
67079	52	66.67	43.33	5.08	8.04	9.8	22.94
720053	59.33	47.00	28.67	3.63	4.9	7.26	15.78
720132	60	63.33	44.67	2.16	7.84	13.72	23.72
Local	62.67	57.00	31.67	2.84	7.25	10.68	20.78
CV %	30.1	17.8	23.6	26.4	15.4	22.7	19.0
SED				1.79	3.55	9.66	10.7

Table 18. Tuber quality and earliness of new potato lines tested in farmers fields

Variety	Tuber quality	Foliage at harvest
67079	Tubers not uniform, pale whitish skin, white flesh	Foliage completely dead
720053	Roundish tubers	Starting to senesce- foliage collapsed, some pale green plants
720132	Skin dark yellow, oval shaped, white flesh	Starting to senesce- foliage collapsed, some pale green plants
Local	Red skin, yellow flesh, oval shaped and mostly large tubers	Foliage completely dead

Statistically, there were no significant differences in the yield of the different varieties. However, highest total yield was observed in entry 720132 (23.7 t/ha) and 67079 (22.9 t/ha). 720053 yielded the lowest (15.7 t/ha). Our local check yielded 20.7 t/ha. The entry 67079 seemed to be the earliest maturing
Variety since all the foliage was dead by the time of the harvest. However, the tuber skin was very thin and pale yellow, which was not acceptable to the farmers. Farmers pointed out 720132 as the best variety both in terms of yield and tuber quality. Tubers were uniform and oval shaped. Maximum tubers were large. There was no incidence of blight during the growing season. The entry 720132 could be further promoted to be grown in higher altitudes both as a main crop or in the rice based system if planted early.

2.2.9 Seed Quality Assessment of DSC

During the Regional Workshop, a lot of issues were brought up regarding the poor quality of seeds produced by DSC. The Vegetable Sector was asked to validate the quality of the seeds by conducting production trials in the station.
The tests were done only for those crops and varieties that were available from the Agri Input Agency in Wangduephodrang.

Table 19. Performance of different crops and varieties (DSC seeds)

Crop	Variety	Germination %	Yield (t/ha)	Remarks
Chinese Cabbage	Kyoto	91	65.8	No off types
Cabbage	C.Market	86	30.55	No off types
Cauliflower	White Top	88	24.8	No off types
Cauliflower	OP 97	85	21.2	No off types
Broccoli	Atlantic	54	10.25	No off types
Lettuce	Sunny	0	0	
Carrot	E.Nantes	88	17.5	No off types
Radish	SPTN	88	11.6	No off types
Onion	Bombay Red	25	8.67	No off types
J.Green	TaiSai	80	57.4	No off types
J Green	Mibuna	80	32.5	No off types

2.2.10 Seed Production and Maintenance

Table 20. Seed production and maintenance list

No	Crop	Varieties	Remarks
1	Tomato	Roma	Released variety but seed produced for on farm trials as check variety
2	Tomato	Ratan	Bangladesh. Selected being better than Roma in yield longer shelf life and suitable for off season production inside poly- tunnel
3	Bitter gourd	Local	Locally collected from market.. For further trials
4	Yard long bean	TVRC	Seed multiplied for supply to DSC for further multiplication
5	Onion	Red Creole	Italy Rome. Long shelf life though yield is not very high. For further on farm testing
6	Mungbean	Local	For introduction in watershed

2.2.11 Other Activities

Other activities included providing technical assistance to client Dzongkhags whenever the need arose. Certain advisory services were also provided to DSC Bajo in terms of field visits and verification to their seed production problems.
Training on asparagus cultivation was provided for 10 farmers and 5 extension agents from Tsirang and Dagana Dzongkhags and about 10 farmers in Limbukha Geog.

2.2.12 Potato Seed Quality Assessment

The main objective of this study was to study the quality of the seeds that the potato farmers are using and thereby to develop appropriate measures to improve the seed quality. This centre conducted the study in this region, collected information and sample seeds from potato growers. A detailed analysis will be performed by RC Khangma. The information collected and performance of the seeds are listed in appendix 2.

3 LIVESTOCK

3.1 FEED AND FODDER RESEARCH

On-station Activities

3.1.1 Introduction nursery tree species.

This trial was established in July '98 with an objective to introduce and evaluate legume tree species with potential for fodder, green manure, weed control and soil fertility management. Each plot of 100 X 50 cm has 12-20 trees in 2 rows with 2m spacing. Weeding was done where necessary. Two measurements of plant height at 60 days interval after planting were done (results in table 21 below)

Table 21: Legume tree species tested with their average height, survivability, and seed collection.

Entry	Av. Ht. (m) 60 Days	Av. Ht.(m) 120 Days	No. of plant surviving	Seed collected (gm)
1. Leucaena leucocephala 70	0.44	0.79	12	153.07
2. Leucaena leucocephala K 636	0.44	0.77	12	108.54
3. Leucaena diversifolia Ex Philipensis	0.48	0.77	12	251.55
4. Leucaena pallida Ex Nepal	0.58	0.97	12	111.63
5. Leucaena pallida 14189	0.72	0.84	12	-
6. Leucaena pallida 14203	0.78	0.89	10	-
7. Callindra callothyrsus	0.53	0.92	1	-
8. Sesbania sesban 10865	2.53	4.27	10	-
9. Sesbania sesban 1238	2.10	3.50	9	-
10. Sesbania sesban 1261	2.09	3.37	6	-
11. Sesbania sesban 1265	1.83	3.77	9	38.64
12. Sesbania sesban 1284	1.70	2.68	8	-
13. Sesbania sesban 1290	1.56	2.36	6	-
14. Sesbania sesban 15019	1.64	2.85	9	22.11
15. Sesbania sesban 15021	2.28	3.67	9	123.00
16. Sesbania sesban 15036	1.79	3.56	12	19.18
17. Acacia villosa	0.55	0.81	2	-
18. Crotalaria anagyroides	1.47	2.00	12	713.75
19. Flemingia macrophylla	0.56	0.92	12	217.54
20. Gliricidia sepium Retalhuleu	0.62	0.86	1	-

Out of the 20 entries, evaluated for their growth (height and vigour) at 60 and 120 days intervals, *Sesbania sesban*, varieties 10865 & 15021 were the best performers in terms of height growth. Subsequent measurement at 60 days interval could not be taken as the trees had attained a height inconvenient for measurement. Early in February 2000, seeds in small quantities from some of these nursery trees were collected for multiplication. These trees were later pruned in February 2000 at 1m height to observe its re-growth and branching capacity. During the next season, the biomass yield will be assessed. Some of the entries of *Sesbania* varieties, *Crotollaria and Gliricidia* died after pruning. Observation of this trial will continue till 2002.

3.1.2 Sugarcane Accession and Evaluation.

The objective of this trial is to evaluate local / imported sugarcane varieties for adaptation to Bhutanese conditions, suitability for use as winter fodder and dry matter production. Initially, 8 local collections were brought and planted at the station to observe their biomass yield at 300 days and height and vigour after every 100 days interval. Details till first harvest are as in table 22 below.

Table 22: Height and biomass assesment of sugarcane

Local Collection	100 days Ht. (m)	200 days Ht. (m)	300 days Ht. (m)	Biomass yield of tops /leaves (Kg)	Av. No. of tillers/pit
AF Nursery	0.56	2.02	3.23	47.70	8.1(9 survived)
Tandin Bajo	0.62	1.91	3.50	31.36	7.9 (7survived)
GC (kitchen garden)	0.51	1.90	3.37	48.18	11.4 (9 survived)
Zingsay, White	0.49	2.82	3.44	39.00	8.1(10 survived)
Zingsay, Black	0.64	2.90	3.37	22.70	8.1 (9 survived)
Bap, Wonjukha	1.11	2.86	2.84	38.00	7.9 (10 survived)
MG (kitchen garden)	1.33	2.79	3.16	60.60	11.4(10 survived)
Tshering, Lhaku	1.80	2.35	2.60	45.90	9.3 (10 survived

From the 300 days height measurement, the local collections, Tandin Bajo had attained maximum height of 3.5m followed by Zingsay White with 3.44m and GC and Zingsay Black with 3.77m. However, MG (kg) recorded highest biomass yield of 60.60 Kg at 300 days harvest followed by GC (kg) with 48.18 Kg and AF Nursery with 47.70 Kg.

Additional nine local collections were brought from Gaylegphu and Tsirang and planted in mid January this year. Two cuttings per pit of total 10 pits were planted. Out of nine local collections, only one local variety (*Seto Gaomaray)* failed to emerge and later found rotten. Rest is doing well.

Also, replicates of first eight local collections were also planted in February the performances of which are good till date.

3.1.3 Winter Fodder Seed Production.

The objective is to test appropriate forage species with potential to produce higher biomass yield of green fodder and tolerate 2-3 cuttings per season. More importantly, the sector is trying to bring out the best mixture combination fodder (grass & legume) and at the same time produce seeds for multiplication and distribution. Oat and Rye showed good emergence but Vetch did not germinate. This may be due to old seed stock losing viability. At the later stage, Rye died too, as a result of water logging after irrigation. However, oat atleast recovered the seed. The poor performance of the winter forages may be due to poor/untimely irrigation, poor soil fertility that may have resulted from continuous cropping, repeated use of same seeds with narrow genetic base and inappropriate seed rate used. Nevertheless, last season, separate seed rate trial for oat in a plot size of $10m^2$ in 3 replicates with 3 treatments (100 Kg, 150 Kg and 200 Kg/ha) were tried. Results are as below:

	Replicate I			Replicate II			Replicate III		
Seeds rate (Kg/ha)	100	150	200	100	150	200	100	150	200
Yield (Kg/$10m^2$)	8.5	7.5	10.0	8.0	8.5	11.0	8.0	10.0	8.5

Totals:

100 Kg/ha. = 24.5 Kg/$30m^2$ plot.
150 Kg/ha. = 26.0 Kg/$30m^2$ plot.
200 Kg/ha. = 29.5 Kg/$30m^2$ plot.

The above results indicate that higher seed rate would give higher yield. But, this may not be true as literature cites a lower seed rate of 80-90/ha and 70-110 Kg/ha. To deduce a correct seed rate under our conditions, more seed rate trials need to be conducted.

3.1.4 Tree Fodder Plantation / Demonstration Purposes.

Fodder tree seedlings were planted since 1994 with an objective to observe their adaptability and fodder production capacity. Some of the fodder tree species like *Gmelinia*, *Ficus*, *Melina* and *Leucaena* were planted along the fodder block boundary. Out of the 12 *Gmelinia* trees existing, biomass of 7 was taken randomly. An average of 60.7Kg fresh weight was recorded from each tree.

In addition to the existing *Ficus* trees, 51 *Ficus roxburghii*, 12 *Ficus semicordata*, and 10 *Ficus bengalenis* and cuttings of *Gliricidia sepium* and *Ficus elastica* brought from Lingmethang were planted around the field boundary.

18 random samples of *Leucaena leucocephala* tree maintained as hedgerow trees were felled and assessed for fresh weight. An average of 6.3 Kg of fresh weight was recorded from each tree (height about man-height).

3.1.5 Napier (*Pennisetum purpureum*) Grass Slips Production/ Distribution.

Napier grass also known as Elephant grass, a coastal climate loving grass is a cane like grass with thick, strong stems that may reach to a height of about 15 feet. It has

an extremely extensive and deep root system, that makes it tolerant to dry conditions. Main growth is in summer when the temperature and humidity are high. Little growth occurs during cooler months and it is susceptible to frost. It is best adapted to fertile soils. Very high yields of forage of around 260 Kg/ha can be harvested annually. This grass has been grown in Bajo since early '96.

It has been largely propagaated vegetatively by planting hard stem pieces about six months old bearing 4-5 nodes. The centre has more than 1000m2 under the grass and is now available for distribution.

On-Farm

3.1.6 Stall Feeding Practices in Tsirang.

The survey was carried out in thirteen villages of three geogs under Tsirang dzongkhag where stall-feeding practices were mostly concentrated. The objective was to obtain first hand data and understanding of the existing system in practice and to document and learn from the experience of farmers who are practising stall-feeding. Information gathered shall be used to improve and promote the practice in other areas.

In all the geogs surveyed the farmers keep 1-3 cows on a purely stall-fed basis. However, most of the farmers keep 5-22 heads per household a less intensive Day-out and Night-in system. Jersey cross is the common breed kept under this system. Jersey crosses of 25-90 % are kept under this system depending upon the owners' immediate needs and availability of feed. The survey gives evidence that Jersey crosses of 80-90% are the only breed profitable in such a system. The stall-fed cows are dependent mostly on *Kholay* (Wet feeding) prepared from locally available feed ingredients. These cows also receive green fodder and straw as supplement in the stall. The labour requirement is met by the family labour, upon which depends the number of cows kept in stall-feding. To keep more than three heads, a family would require more labour than currently available.

The breed type and land topography plays an important role in the adoption of stall feeding practices. Also, farmers' interest and availability of family labour has brought this change in the existing traditional system. Scarcity of feed and forages in winter was reported as critical. This constrains most of the farmers from shifting to Stall-feeding. In general, for a farmer to adopt stall-feeding practice, he/she should have keen interest, family labour, feed resources and keep a maximum of three heads of pure-line Jersey cows to be profitable. (For details, refer RNRRC, Bajo *Technical Paper No. 3*, May 2000*).*

3.1.7 Legumes in Orange Orchard.

The objective of this trial is to optimise forage production with horticultural crops (especially in orange orchards). It has the second objective to study the comparative advantage of leguminous forages inter-cropped with orange in terms of input requirement, soil conservation and soil fertility management, and ground cover as a cover crop with the traditional system of management and production of forages separately.

As a nation wide trial, one site under Wangdue and other at Punakha was established in May 1997. GLD and Pintoi were compared with a control. Pintoi is found growing well but GLD had failed. The poor performances of the trial may be due to the frequent change of the caretakers and the negligence of the owner. However, observations after the two years reveal that both of these legumes can do well in orchards provided care and inputs (seeds and fertiliser) are committed. Similar trials shall be initiated in other dzongkhags with interested and co-operative farmers. This trial shall continue till 2005.

3.2 Breeding and Management Research

3.2.1 Breed Preference for Dairy Production in Gasa Dzongkhag.

Livestock rearing is an important occupation of the farmers of Gasa. They are a major source of livelihood and income providing milk and related products, draught power and manure. The ruminant population is mainly yak in the high altitude while cattle dominate the lower areas. The farmers living in the lower areas has shown interest in opting for a suitable breed that can tolerate the prevailing climate, adapt to the rough terrain and provide fairly good milk and higher butter yield with minimum management.

Traditionally, the farmers rear mainly *Jatshamin* and *Yankumin* for milk and draught. However, the farmers of Khamae and Khatoe are increasingly looking for a change from *F1* level crosses of *Mithun* and *Thrabam* to *F2* level crosses of Jersey and Brown Swiss. The prospective breed would definitely adapt to their conditions and benefit them at large. Also, the new breeding technique appears technically sound economically efficient and socially acceptable as supported by the findings of the survey. Though, these breeds would demand little additional management on and above the existing management but the farmers would enjoy a better yield. Details of the survey are available in a report published by the centre.

4 FORESTRY

4.1 Introduction

Forestry research program of the centre has so far concentrated mainly on community forestry and agroforestry projects of the social forestry sub-program. With the identification of two Forest Management Units (FMU) for research namely Khotokha and Rimchu, however, modest attempts into mainstream forestry research particularly in the silvicultural discipline are being made.

Many of the activities of the research program are long term and on-going. During the fiscal year 1999-2000, routine maintenance and assessment of these activities have been done and a few new activities have been initiated.

The activities of the program, for the purpose of this report, has been divided into four viz. activities at the centre, activities in the Lingmutey Chu watershed, activities in the and FMUs.

4.2 Activities at the Centre

4.2.1 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**.** The species raised and evaluated are given in table 1.

Table 23: Tree species in the Agroforestry nursery.

Species	Seed source
Spondias auxillari	Rurichu
Schima wallichii	Punakha
Carpinus viminae	Rimchu
Eucalyptus spp	Bajo
Alnus nepalensis	ICIMOD Nepal
L .diversifolia	Bajo
Cupressus spp.	Matalumchu
Quercus griffithii	Limbukha
Ficus roxburghii	Tsirang
Jacaranda	Punakha/Sonagasa
Eriolobus indica	Nahi
Toona celiata	India

4.2.2 Development of Vegetative Techniques

The objective is to develop improved vegetative propagation techniques for various multipurpose tree species (MPTS). Thump size (10-12mm diameter) and 15-30 cm long cuttings were made for each of the species with sharp secateurs during February March and inserted into pre-papered holes in the nursery and allowed to root. All the species considered respond well to the vegetative propagation techniques.

4.2.3 Propagation of bamboo through seeds, rhizomes and nodes

The propagation through seed method is effective and useful especially if we are to produce a large numbers of field plantable bamboo seedlings. The technique and the methods involved are simple.

Pre-treatment by keeping seeds in cold water up to 12 hours was done. Seeds are then sown in polybags. Two types of sowing were done namely sowing in polybags and in raised seed beds. In the former type of sowing, 3-4 seeds were sown in each polybag containing a germination mixture of sand and soil up to 5mm. This enables easy maintemnance. The latter involved preparing 4x3 feet seedbeds into which seeds are sown thinly seeds thinly (sowing too thick ay hamper rhizomes formation). The substrate used was loose soil/ or soil with sand.

Till germination, the moisture content was kept reasonably high. Watering after germination was done only when necessary. Protection of seeds from rodents such as rats and insects is important, so some insecticides was applied.

After germination, rhizome formation took place only after 3 months. After rhizome formation mass propagation was achieved by dividing each shoot with rhizomes attached. This method has been very successfully used with *Dendrocalamus strictus, Dendrocalamus spp, and Bambusa arundinacea* with success rate of more than 90 percent. Table 2 gives some results.

Table 24: Bamboo propagation through Rhizomes

Species	Planting Time	Annual shoot Production		Annual Dia. Increment		
		1999	2000	1998	1999	2000
Dendrocalamus hookerii	8.5.98	2	7	12	15	20
Bambusa nutans	8.5.98	1	2	<10	<10	13
Dendrocalamus hamiltonii	28.5.98	nil	2	nil	<10	15
Bambusa calvata	28.5.98	1	3	<10	14	15
Himalayacalamus hookerianus	11.6.98	Did not survive				
Yushania maling	10.5.98	Did not survive				

Among the species tested, *Dendrocalamus hookerii, Bambusa nutans, Dendrocalamus hamiltonii, and Bambusa calvata* are performing well.

4.2.4 Performance evaluation of leguminous shrub species

Five leguminous shrubs species brought from ICIMOD and Philippine were planted at the centre to evaluate their performance and also for seed production purposes. Table 3 gives the species according to source.

Table 25: Leguminous shrub species and source

Species	Seed source
Desmodium ransoni	Philippines
Flemingia macrophyllas	Philippines
Sunhemp	ICIMOD
Calliandra	ICIMOD
Indigofera	ICIMOD

The other species planted for soil improvement and suitable in the agro-forestry is *Tithonia diversifolia* (Wild sunflower) which is performing well in the centre as well as in the Watershed. This species has potential to be used in the dry land cropping system, wherein it can be used as hedgerows and for biomass production that can be used as manure for the crops. Literature cites that the leaf biomass contains phosphorous which adds nutrient to the soil. Its effect on soil nutrient under our conditions needs to be studied.

4.3 Activities in the Watershed

RNRRC Bajo initiated the Community Based Natural Resources Management (CBNRM) 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.

Under the above components the research program took up the following activities as part of the above research theme: community forestry nursery (CFN), community forestry plantation (CFP), permanent resource monitoring plots and rapid silvicultural assessment (RSA).

4.3.1 Community Forestry Nursery

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 is given in table 4.

Table 26: Species available in 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*

4.3.2 Community Forestry Plantation

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. A further 3.04 hectares and 2 hectares were planted in 1999-2000 at Omtekha and Wanjokha respectively. Table 5a and 5b gives the list of species.

Table 27: List of species planted at Omtekha (99-00)

Species	Quantity
Cupressus	951
Quercus griffithii	779
Melia azedarach	336
Spondias spp.	151
Leucenea diversifolia	290
Albizzia procera	119
Dendrocalamus strictus	10
Ficus bengalensis	10
Poplar	30
Tongshing	84
Total	2760

4.3.3 Permanent Resource Monitoring Plots

The rural people depend on the forest for a lot of products viz. fodder, firewood, construction and fencing materials and leaf litter and also grazing. Forest exhibit significant changes over time and these changes are mostly determined by the use of the forest. Wanton cutting down of trees for firewood or construction would

ultimately lead to forest depletion. Also more often than not some species are preferred over others and as a result these species are continually taken out from the forest leading to forest degradation. Collection of leaf litter has also been suggested to be detrimental to forest quality as this activity removes the organic material from the forest floor whose decomposition otherwise would help in maintaining the fertility of the soil. The extent to which a forest is used depends on its species composition and proximity to the homesteads i.e. diverse and forest closer to the homesteads are used more intensively.

Establishment of sample plots for monitoring forest change according to use at different altitudes, aspects and according to dominant species (forest type) and periodical observations would over time generate information on the forest dynamics of such forest with respect to the use they are put to. Information gathered in this way would help in understanding the dynamic processes, which is important from both scientific, and management perspectives.

The objectives of the activity are to 1) monitor forest change in terms of growth and species diversity over time; 2) ascertain the effect of current forest use on the sustainability of these forests; 3) to understand and document the ecological dynamics of the forest types under study.

Eight permanent plots were established in the watershed (2 in the Rhododendron dominant forest; 2 in the oak dominant forest; 2 in the transition zone of the oak and pine forest; 2 in the pine forest). This way a representative sample of the forest in terms of forest type, altitude and aspect is achieved. The sizes of the plots are 20 x 20 m. Plots have been selected randomly in the four areas as above.

A map of location indicating the exact site of the plots has been prepared. Complete inventories of trees consisting of tree height, diameter, etc. in the plots were taken and individual trees were marked using paint. Other plot-wise observations such as slope, aspect, soil type were also be recorded.

The following variables will be measured for each tree in each plot: tree number; tree species; diameter at breast height (dbh); tree height; grid reference (grid of 20/20 developed during establishment; damages, pest and diseases (bark damage by deer, bark beetles, fungi, etc.); and remarks (e.g. forest fires, grazing intensity).

4.3.4 Rapid Silvicultural Assessment

In co-operation with NRTI, BG-SRDP, Lobeysa and RNRRC, Yusipang, a Rapid Silvicultural Assessment (RSA) of the Lingmutey Chu watershed forest was carried out from 22-27 May 2000. The objective was to elicit through discussions with the community focus groups on their perception of the forest quality and quantity.

There are basically three types of forest in the watershed viz. Chirpine forest, Mixed Chir-broadleaf forest, and broad-leaved forest. On the southern slopes one finds *Michelia* and *Carpinus* sp. As dominant species while *Q. Lanata* and *Q. Semicarpifolia* dominate on the north facing slopes. *Q. Griffithii* is the dominating species on the base of the slopes near the homesteads and serves as sogshings ideally. *Rhododendron* sp. Forms the major understorey species with occasional

Lyonia sp. And *Symplocus.* Topography is defined by hill slopes which are occasionally steep and characterized by rock outcrops in certain areas. The forest slopes down towards north and slope giving the two major aspects viz. North and south. The elevation of the forest goes from about 1600 m above sea level on the lower Chir forest dominated slopes to upto 2500 m at the top with *Quercus* forest.

Red soils are predominant in the lower slopes while brown sandy clays are characteristic of soils on the upper slopes. Deeper and higher up into the forest brown earth with dark and thick humic layers are found. Bilberry (*Vaccinium* sp.), bramble (*Rubus* sp.), and *Illex* sp. Are the major ground vegetation. The soils have fairly good drainage although some poorly drained and marshy areas are present.

Forest in the watershed has increased in area in the watershed consequent to protection after the nationalisation of the forest. This is apparent from the young stand especially chir pine, growing in the former pasture and waste lands. However with no proper sivicultural system having followed, the villagers taking out the best trees and leaving the poor trees to be seed bearers and those closer to the homestead the quality of the forest particularly those around the settlements have considerably deteriorated. Existing trees in the forest exhibit low yield and as such productivity of the forest may be doubted. Even deep inside the forest in some areas visited the forest is poor in terms of quality with inadequate or no regeneration at all. Grazing may be one of the primary reasons for the lack of regeneration manifested by frequent citing of browsed seedlings. Another reason may be because of a paucity of seeds falling on the ground or a lack of favourable microsite.

A summary of results from the preliminary analysis of the assessment is listed in appendix 3.

4.4 Activities in the FMU

Recognizing a want of mainstream research by the forestry program during the second National Forestry Co-ordination Workshop, two Forest Management Units (Khotokha and Rimchu) were identified as possible sites for research.

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 has been 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.

Research plots have been identified and demarcated. Thinning treatments shall be applied in November – December 2000 when the trees cease to grow.

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 regeneration survey as part of a training workshop for territorial foresters in collaboration with NRTI and BG-SRDP has been carried out. Guidelines developed by the FRDD were used. Results have not been analyzed.

4.5 Conclusion

The research program has been able to successfully monitor and continue with all on-going activities and implement few new activities such as permanent resource monitoring plots and rapid silvicultural assessment and regeneration survey in Rimchu FMU. Besides the research program also collaborated with the RNRRC Jakar in a study of Fir and Mixed Conifer forest dynamics in the Black Mountain National Park.

5 SYSTEMS RESOURCE MANAGEMENT

5.1 Community Based Natural Resources Management (CBNRM)

CBNRM was further continued in the Lingmuteychhu Watershed during 1999-2000. Research intervention was mainly focused on the problem addressed during the problem diagnostic survey conducted and is implemented under each research theme. This report presents the activities and results of 1999-2000.

Crop production and Management Research

5.1.1 On-farm Paddy variety for High altitude

RNR RC, Yusipang, initiated the trial in collaboration with this research center, since lack of blast resistant rice varieties is an important constraint of the rice farmer of high altitude. Farmers have a limited choice of varieties to grow and the local varieties most preferred by the farmers are highly susceptible to blast. Therefore there is a clear need for identification of blast resistant rice varieties. In an attempt to develop blast resistant rice varieties a rice blast hot-screening and selection programme was conceived in 1996 at Gyenakha. After four years of selection materials are available for further testing in the farmers' fields under farmers' management.

Seeds weighing 1 kg each of 4 tested and promising rice varieties were provided from this center to volunteer co-operators of high altitude area at Limbukha village. The farmers did nursery raising and management themselves. Out of the four varieties tested the results are as follows:

Table 28: Germination, Seedling vigor and cold tolerance of high altitude paddy varieties

Farmer	Variety	Sowing date	Germin-ation	Transplanting date	Seedling vigor	Cold tolerance
Kuenga	PP3-31-2-1	1/4/2000	Nil	-	-	-
Gomchen	PP322-1-2	1/4/2000	nil	-	-	-
Chhimi Rinzin	PP2(38-4)	1/4/2000	Yes	13/6/2000	Extra vigorous	Seedling dark green
Am Nam	PP4-8-1-1	1/4/2000	Yes	10/6/2000	vigorous	Seedling light green

Evaluation on Blast, Plant height, Tiller number and Grain yield will be continued in the following years.

5.1.2 Farmers evaluation on released paddy varieties.

This trial was carried out to address the farmers' evaluation on the performance of the released improved rice varieties viz. Bajo Kaap I & II and Bajo Maap I & II under farmers' management condition.

The trial was established in the mid altitude area in four sites at Omteykha, Matalungchu, Wanjokha and Thanju villages with 12 cooperators in total. All the

tested varieties have good germination and seedling vigor. The seedlings have been transplanted. Evaluation on the tiller number, grain yield and milling recovery will continued.

5.1.3 Shochum Control campaigns.

Shochum *(Potamogeton distinctus)* is a major weed problem in the wetlands of the watershed. The farmers practice only one hand weeding and cannot afford chemical control owing to the high purchase price of the chemical. Therefore, to control the weed problem in the flooded wet land, Shochum control campaigns through intensive hand weeding was initiated by the Research center in two locations viz. Limbukha and Omteykha villages. Selection of the farmers was done based on their interest and selected farmers were required to do intensive hand weeding for 3 times. The weeding of Shochum is done after every two weeks interval. The field size varied upon the cooperator (Table 29). The intensive hand weeding will be observed for 3 years to compare the result of the past and then. So it will be further continued and monitored.

Table 29: No. of farmer involved and time spent for hand weeding

No	Village	Plot size	No. of farmers involved	Time spent
1	Limbukha	1 terrace (10		
	1st Weeding	Decimal)	7 farmers (6 F and 1 M)	1 hour
	2nd Weeding		3 farmers (2 F and 1 M)	3 hours
	3rd Weeding		3 farmers (2 F and 1 M)	4 hours
2	Omteykha	1 langdo		
	1st Weeding		3 farmers (2 M and 1 F)	1 day
	2nd Weeding		5 farmers (2 M and 3 F)	1 day
	3rd Weeding		2 farmers (1 M and 1 F)	ys

5.1.4 Asparagus promotion under trained and improved management.

During the feedback presentation conducted in the Lingmuteychhu watershed in June 2000, most farmers reported unavailability of Asparagus seedlings for crown production. So, Asparagus seedlings were distributed in Dompola, Wanjokha and Thangju villages on promotional basis by training the farmers on planting and management practices. Asparagus seedlings were distributed to 18 cooperators of Thanju and Wangjokha and 13 farmers from Dompola and Lingmukha.

5.1.5 Demonstration Orchard Trial

Evaluation of station-proven planting materials in farmers' fields has been a pre-requisite and mandatory before recommending the materials for general cultivation or planting. The objective of on-farm testing are to: a) identify single superior genotype that perform best under farmers existing management capability and capacity; and b) to test suitability of materials under major diverse agro-ecologies. Therefore, a demonstration orchard was established at dry-subtropical zone (altitude 1600 meter) with an acre of land, at Omteykha within the watershed with the following objectives:

1) The identified sites will serve as the representative sites of major agro-ecologies in the region,
2) The site will also serve as test sites for all fruit species,
3) It will serve as a permanent site to monitor longevity of new planting materials (especially the vegetatively propagated ones) over years.
4) The site in long run will serve as a demonstration plot.

The tree crops planted in the demonstration orchard till date are in table 3.

Table 30: Fruit plants at Omteykha demonstration orchard

Species	Variety	No. of plants	Date of planting	Remarks
Citrus	Valencia O (Ca)	5	24/02/2000	All the citrus plants have survived.
	Nules (Tc)	5	24/02/2000	
	Oota Ponkai (Tc)	5	24/02/2000	
	Okitsu wase (Tc)	5	24/02/2000	
	Fremont (Cm)	5	24/02/2000	
	Minneola (Tc)	5	24/02/2000	
	Ichepumi (Tc)	5	24/02/2000	
	Mayer (RM)	5	24/02/2000	
	Encore	5	3/07/2000	
	Pears	5	3/07/2000	
Sub-tropical Apple	-	12	29/02/2000	Including 2 pollinizer
Chestnut	-	5	28/03/2000	1 plant dried till date.
Apricot	-	5	28/03/2000	
Pomegranate	-	5	28/03/2000	

A total of 67 fruit plants have been planted, since it is a long-term demonstration plot, monitoring of the orchard will be continued.

Crop-Livestock Interaction (Feed and Fodder)

5.1.6 Monitoring community breeding bull management and Pasture development

A mithun bull was placed at Nabchhey village in April 1999 with the financial assistance from Bhutan-German Sustainable RNR Development Project (BGSRDP) in Lobeysa. The main reason for the supply of this bull is to increase mithun cross cattle population in the locality and to assess the potential of mithun breed in the area. The bull is now about two and half year old but had not yet attained services. The bull is let loose to graze with the community cattle and at night it is kept in the bull shed. Monitoring on the services performed and progenies born will be recorded and continued.

The community had extended their pastureland from a langdo to an acre. Earlier the community cultivated Sudan grass as a improved summer pasture to feed the bull and also to control surface soil run-off. However Sudan grass being an annual plant, farmers prefer to cultivate perennial pasture species. Accordingly

Researchers have provided with temperate pasture mixture seeds compromising of grasses and legumes (Cocks-foot, Italian Rye grass, Tall fescue and White clover) for an acre of land and this has been sown in the pastureland. Few species have germinated but are heavily ingested by weeds. As such the farmers have been advised to weed. Monitoring shall be continued.

5.1.7 Fodder tree monitoring

Winter fodder shortage is the primary constraint for the farmers of the watershed, affecting production capacity and the health of the livestock during the lean season. In order to overcome the winter fodder scarcity the farmers were distributed with Fodder tree seedlings *(Ficus rhoxburghii)* in 1997 and till date lopping of these trees have not yet begun. Also in Nabchhey village the fodder trees were severely attacked by insect pests that eat the leaves. Samples of the pests have been collected and submitted to IPM sector. The fodder tree monitoring and evaluation will be continued.

5.2 Integrated Plant Nutrient System Research

5.2.1 Rice Crop cut report

The paddy fields in Rinchengang are used very intensively, three crops per year, i.e. mustard in winter, rice in spring and rice in summer. But when it concerns soil nutrient management, they perhaps only urea fertiliser at the rate of 3-5 *dreys* per *langdo,* as a single top-dressing after weeding. All the farmers used to apply FYM ranging from 18-30 baskets per *langdo* depending on the availability of FYM. These practices refer to rice only, both spring and summer crop. For mustard, the application of FYM is same as that of rice, but they apply less amount of urea, 2-3 *dreys* in one *langdo* as a top dressing after first irrigation.

Every crop harvest removes certain amount of nutrients from the soil, it is not known to what extend that is being replaced back to the soil. Since crop yield is one of the biophysical indicators, which reveals the soil nutrient status, a random crop cut was considered worth taking. So, this crop cut exercise was aimed at establishing a benchmark rice yield for Rinchengang and also to assess the incremental yield loss with intensive cropping system with the same management practices.

Six farmers were selected randomly for the crop cut exercise. Three crop cuts of $5m^2$ were done for each farmer. The crop variety and the moisture at harvest were noted. The yield figures in table 1 are the average of the three crop cuts. Results of the crop cut indicate that IR-64 yielded the highest than the other local varieties. The difference is very significant. Jasay yielded the lowest (table and figure on the next page).

Figure 5: Results of the crop cut at Rinchengang

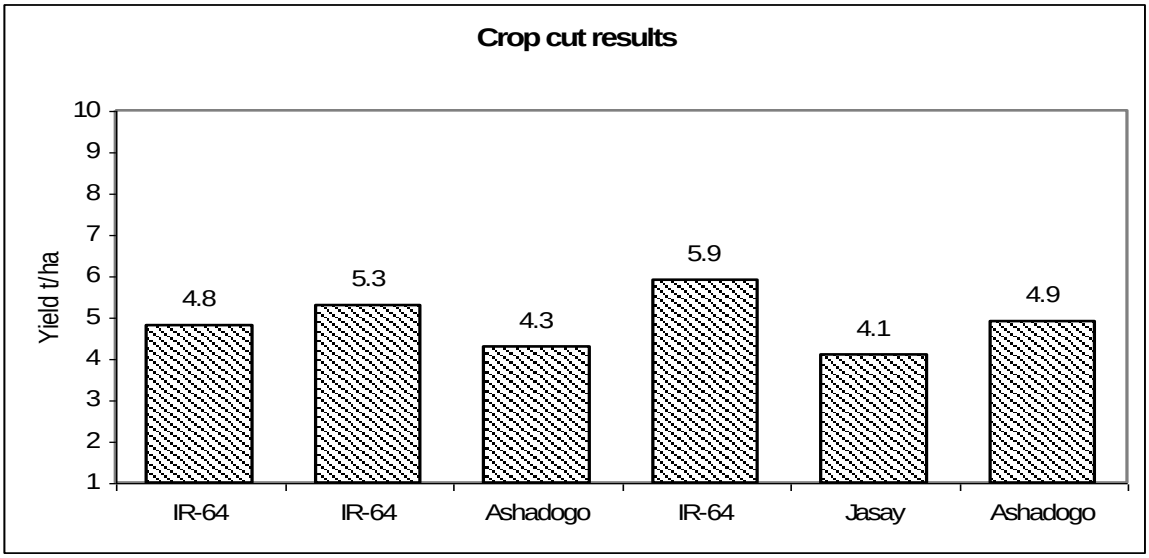


Table 31: Results of the Crop cut at Rinchengang

Farmer	R.variety	Yield kg/5m^2
Chado	IR 64	2.5
Ap Aga	IR 64	2.7
Kakam	Ashadogo	2.2
Dechem	IR 64	3
Lenchu	Jasay	2.1
Kuchu	IR 64	3

Rice yield figures are not very low under such management practices. However, it will be worth continuing the exercise after every three to four years. The results shall keep farmer, researchers and extensionists informed on the soil nutrient status in these fields.

5.2.2 Report on Soybean Varietal Evaluation

Legume cultivation is very limited either as a sole crop or as an inter-crop. Seed scarcity is the main reason for this. The varieties at present available with most farmers are local cultivars and AGS 258 and 327 with one test farmer.

Soybean is used for home consumption as well as for sale. Improved soybean varieties are being screened at the RNRRC Khangma for the purpose of both sole and inter-crop cultivation. Five improved varieties, namely AGS 258, AGS 327, AGS 73, AC 86018-427-3 and Bragg have been received from RNRRC Khangma which have been identified for further evaluation on-farm. This evaluation trial was carried out in Dompola with one test farmer.

The objective of the trial was to evaluate the yield of five improved soybean varieties at farmer-managed conditions as a sole crop and to assess farmers' preference of the new varieties.

Five improved soybean varieties with local as check were sown on a plot size of 15m^2 for each variety. Researcher and the extension agent laid out the trial with in cooperation with the farmer. The farmer did himself all other agronomic practices. Timely monitoring was done by the researcher and the extension agent. Yield assessment per variety was also done for the whole trial area at harvest.

Pest disease incidence was not observed in all the varieties. All the improved varieties matured two weeks earlier than the local variety and farmer commented that this gives them ample time for land clearing and preparation for the next crop. The cooperator farmer remarked that Bragg and AGS 73 dropped their leaves before harvesting which makes their work easier during threshing as there is less dried leaves to clean. They found that AGS 73 and AGS 327 have more pods per plant compared to other varieties and they think that more pods means more yield. However, they liked Bragg for its big whitish seeds. The results showed that the performance among varieties did not differ significantly. The test entries could very well serve as alternative varieties under Dompola's environmental condition. The yields of these varieties at the station trial at the RNRRC Khangme range from 1253kg-1690kg/ha (Khangma annual report, 1997-98). It could be summarized here that, yields of these varieties tested under farmer's managerial conditions are reasonable (Table 1).

Table 32: Yields of different soybean varieties.

S. variety	Yield (kg/15m^2)	Yield (t/ha)	Remarks
AC-86018-427-3	1.9	1.21	Test entry
AGS-258	2	1.30	Test entry
Bragg	1.8	1.13	Test entry
AGS-73	1.6	1.00	Test entry
AGS-327	2.2	1.40	Test entry
Local	1.8	1.12	Local check

All the varieties performed well and gave good yields, meaning these varieties are feasible to be cultivated at Dompola's environment. The yield of different improved soybean varieties did not indicate a difference between the management practices of soybean cultivation.

5.2.3 Nabchhe Maize Crop Cut Report

Maize is the staple crop of Nabchhe community and generally sows it in the months of April and May and harvest in the months of September and October. They grow two maize varieties namely local varieties and improved varieties particularly Yangtsipa.

Maize fields are ploughed twice and seed broadcasted. Chemical fertilisers are never applied and those farmers who do not have enough FYM apply FYM on a

priority basis. Weeding is done twice, first at knee high and second at tasseling /cob formation.

With these management practices, the exact yield figures of different maize varieties are not known. Besides the need of this yield data for research purposes, the yield data is needed especially for the economics of crop production survey. As such it was felt necessary to carryout a random maize crop cut exercise to establish the bench mark maize yields of Nabchhe community.

The objectives of the activity are to find out the present maize yield status under farmers' management conditions and to find out the differences in the yields of different maize varieties.

Four farmers' fields were selected randomly at different locations. In each field, three crop cuts of $8m^2$ were taken randomly. Total weights of the maize cobs with husk and without husk harvested were measured. Then the shelling was done to find out the maize grain weight from that same crop cut area. Moisture content at harvest was also noted.

The maize varieties grown were Yangtsipa, local and Pool 9BC1. Two farmers' fields were cultivated purely Yangtsipa. One farmer cultivated Yangtsipa and local and another farmer cultivated Pool 9BC1 and local. From the crop cut result, it is very difficult to say which variety yielded the highest due to mixed cultivation of different maize varieties. However, Pool 9BC1 mixed with local yielded the lowest among the varieties covered under this crop cut exercise (see table 1).

Table 33: Maize crop cut data

M. variety	Cob wt. with husk (kg/8m^2)	Cob wt. without husk (kg/8m^2)	Grain wt (kg/8m^2)	mc at harvest	Std. mc	Grain yield (t/ha)
Pool 9BC1 & local	5.5	4.7	3.7	28.6	15	3.9
Yangtsipa & lacal	11.6	9.7	7	23.7	15	7.9
Yangtsipa	8.8	7.7	5.8	24.5	15	6.5
Yangtsipa	7	6.4	4	25.4	15	4.4

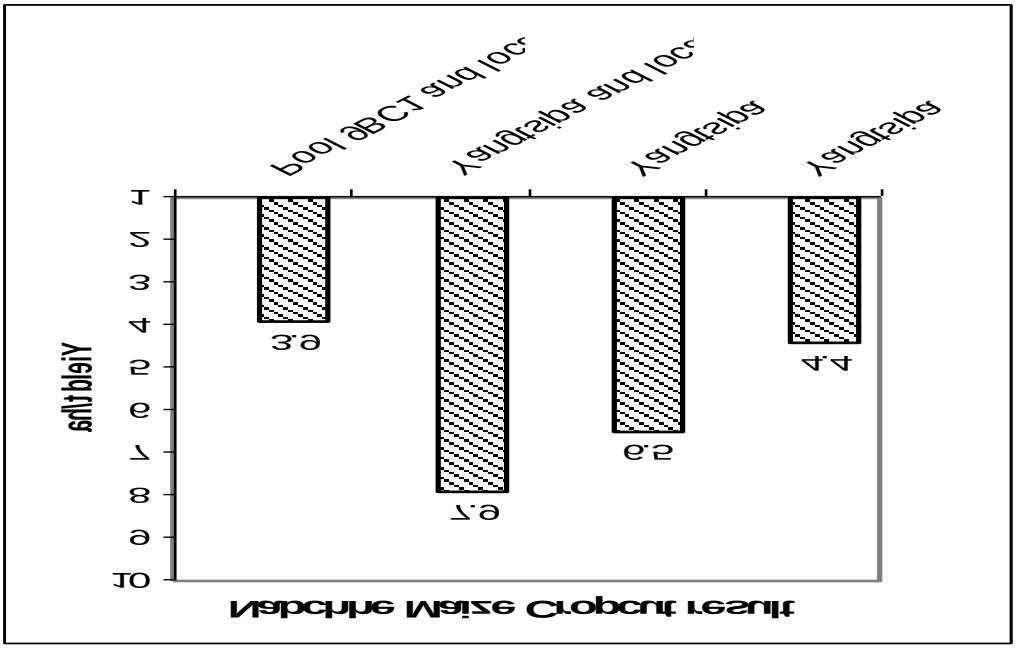


Figure 6: Nabchee crop cut details

Yield figures are not different among the varieties covered under this crop cut exercise. Pool 9BC1 was introduced in the village in 1998 on a trial basis and the trial was carried out to address the low local maize yield problem reported by a test farmer during the participatory need assessment. The co-operating farmer had grown it without mixing with other varieties obtained a yield of only 5.8 t/ha. From the crop cut's result, Pool 9BC1 mixed with local yielded the lowest. This could be either because of the yield of the local pulling down the overall yield or due to a wrong management practice, e.g. sowing time. Thus it could be summarised here that maize variety choice is not limiting and the yields are also not very low. Further yield improvement could be achieved by improving management practices, e.g. increase number of weeding and use of balanced chemical fertilisers if FYM is in shortage.

5.2.4 Balanced Fertiliser Trial on Chilli

In the summer of 1998 a balanced fertiliser trial was conducted in Dompola with one test farmer with three treatments: farmer's practices, urea single top dressing and recommended practices. The results from this trial were encouraging. Farmer's practice yielded 6 t/ha, urea single top dressing yielded 11.33 t/ha and recommended practices yielded 10 t/ha of green chilli. The chilli blight problem was more sever in urea single top dressing and recommended practices plots. Farmers associated high wilt severity in these treatments to good canopy cover, which reduces the light that reached the ground. This trial was done with only one

farmer and the results needed further confirmation. In the following year the same trial was conducted with four farmers in different locations in Dompola.
However, in 1999 there was no chilli harvest from all the trials due to the chilli blight problem. However until flowering the performance was always better in the fertilised plots. The severity of the blight problem is uniform across all locations and among all treatments.

This clearly indicates that the major factor affecting chilli production in Dompola or elsewhere is the blight problem. The differences in the chilli trial yield of 1998 reveal that soil fertility is also a limiting factor for chilli yield, but unless the former problem is solved, improving soil fertility may not have give any results.

5.2.5 Evaluation of Napier Grass for Multipurpose Use

Fodder shortage in winter constrains livestock rearing and hence FYM production especially among those farmers keeping a large number of cattle. Another threat is soil erosion, such as light dark streaked, rills and small gullies affecting the crop yield. To combat this Sudan and Lucerne were tested in summer 1998 but only Sudan proved successful. However Sudan is an annual grass and farmers prefer to replace it with a perennial species, which could control soil erosion and produce fodder all round the year. Napier grass was tested and found suitable as an alternative. It was well established and farmer reported several harvests. Indications of erosion, especially rill erosion have also been reported to be minimised to a great extent within a year. The co-operating farmer appreciated the alternative species i.e. Napier grass that served both the purposes. In June 2000 more slips were planted. This grass could be recommended for the farmers having similar problems.

5.2.6 Soil Sampling as a followed-up of FYM Survey.

FYM is a major source of soil fertility management in the Bhutanese farming context. However, information on FYM availability, quality and time of application is limited. Many farmers in the watershed reported inadequate FYM, but for further intervention better information is needed. Therefore, a survey was conducted in the IPNS sites from May 1998 to July 1999. The initial analysis and reporting on this survey was done with major emphasis on rice, which was the most frequently grown crop (168 of 287 fields surveyed) using the field measurement data. However, for the final report, information on the soil nutrient status in those surveyed fields corresponding to the present farmers' nutrient management practices is felt necessary. Composite soil samples were collected from randomly selected surveyed fields in April-May 2000 and the samples were submitted to SPAL for analysis. The results have not been received.

5.2.7 Establishing benchmark nutrient status in Demo-orchards.

The Horticulture sector in the RNRRC Bajo uses two on-farm approaches to test horticulture on-station trial proven materials. One of the approaches is identifying permanent sites representing various agro-ecological sites and planting and managing the proven materials. These have been called Demonstration Orchards. So far three such orchards are established and two are in the pipeline.

These sites are operating under the full supervision of the research centre. When establishing an orchard, information on the soil of the proposed site is of paramount importance. So the horticulture sector felt it necessary to carry out a pit soil sampling and composite soil samplings from these orchards. In May 2000, in collaboration with the Bhutan Soil Survey Project (BSSP) soil sample collections were done and the samples were submitted to SPAL. Results have not been received.

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

Slope of the land in Nabchhe range from very steep (65%) to a gentler slope (40%). Growing crops on a land with slope of > 65% is not a sustainable land-use practise and farmers have begun terracing their land. Terracing helps to reduce 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.

However, since farmers' long term objective was for terracing their land, the maize trash alone was not very strong for the formation of risers/bunds. This issue was discussed with the farmers and they proposed to try some fodder species on contour lines to stabilise the risers. The other suggestion made was to keep stones on the contour lines.

In consultation with the forestry and the Livestock (feed and fodder) sectors, some legume fodder tree species were identified and were planted in July 1999. Species planted included two *Luceana* species, *Susbiana susban*, *Cotoloria* and *Flemengia*. Saplings were planted with a spacing of 0.5m. A total of 50 saplings, 10 from each species were planted on one contour line. The survival rate of these species was 70% after one year. Farmers observed few rill erosions taking place between these plants during the last rainy season. They proposed planting some grass species, particularly Napier grass between these plants. In June 2000, three grass species were planted (Napier, Guinea and seteria). At the time of planting these grass species, the height of the riser was 0.5m.

5.2.9 Wheat variety adoption study

Wheat is one of the important cereals in the country but there were limited variety choices with the farmers in the 1970s.

The RNRRC Bajo identified two wheat varieties having high yield potential, rust resistance and other important traits and released them in the early nineties. Besides the data on their performance there was no information on the adoption rate of the varieties. This study conducted in Punakha- Wangdue valley in February-March 2000 was explicitly planned to find out the adoption rates and reasons for adoption and non-adoption of the varieties.

A total of 199 households were interviewed using pre-tested questionnaires. Of the total respondents, 177 households had grown wheat. Wheat varieties ever grown were Local, Sonalika, Bajoka-I and Bajoka-II. Wheat is mostly grown for human food, cattle feed and for making alcohol. For all the varieties ever grown

the management practices and inter-cultural operations are the same irrespective of farmer wealth categories.

Local varieties were grown prior to the introduction of present-day varieties such as Sonalika, Bajoka-I and Bajoka-II. Each variety has its advantages and disadvantages. Weighing advantages against disadvantages, farmers change varieties over time. Of the 177 households who had ever grown wheat, 64 (34%) respondents reported growing Sonalika, 51 (29%) Bajoka-I, and 20 (11%) Bajoka-II. Low adoption rate of Bajoka varieties are due to their susceptibility to diseases and pests and also unavailability of seeds. Sonalika is widely grown because of its high yield and early maturity. Yield is the most important characteristic that farmers look for in wheat varieties.

There is no compelling evidence of changes in area of the cultivated varieties neither in the past nor in the future among all farmer categories. Irrespective of the varieties, wheat cultivation in general may either stay the same or slightly increase in future. Labour is the primary constraint that affects the cultivation of wheat across all farmer categories.

5.3 Agricultural Economics

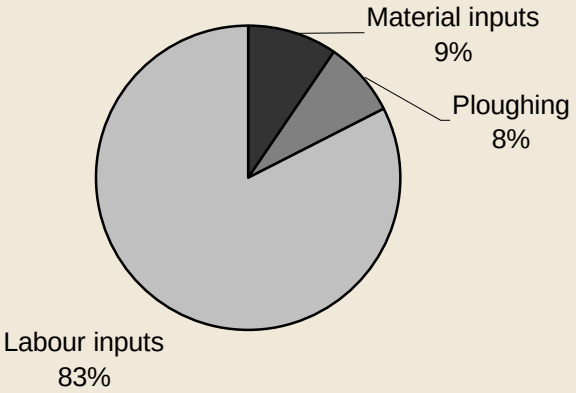
5.3.1 Crop Budgeting (Rice)

A study on the economics of rice production in the watershed was conducted in 1999. The study was conducted with a total of twelve farmers from two selected villages of Dompola and Wangjokha villages in the Lingmuytey Chu watershed, covering 58 rice fields. To ensure a fair representation of the households in the two villages, care was taken to select some households from each of the different 'soil fertility management' categories that had been developed earlier.

Data from the field was collected in 1998. No crop cuts were taken. To minimize recall error, data gathering was done through three separate interviews each conducted just after a particular set of activities was completed. Farmers were asked about their actual labour and other inputs, as well as outputs of each of these 58 rice fields. This study had been conducted with the general objective to understand the costs and returns involved in growing rice in the area.

Figure 1 shows different proportions of total costs in rice production. 83% (standard deviation 24%) consisted of labour cost while material inputs costs formed only 9%, and costs of ploughing accounts for only 8% of the total costs. On the average 205 labour days per hectare was used to grow the crop. Hence it

Fig.1. Proportion of total rice production costs, Dompala - Wangjokha, 1998.



can be concluded that rice production is indeed labour intensive. On an average, rice yield expressed in milled rice from the two villages was 2308 kg/ha (923 kg/acre), with a standard deviation of 1056 kg/ha. The average cost of production of milled rice was Nu. 13.90/kg. The 95% confidence interval of the cost of rice production was found to be between Nu. 9.78 and Nu. 18.02 per kg. This means that probability of cost of rice production within this range is 95%. Total average production costs was about Nu. 25,000 per hectare. Returns to land were calculated at Nu. 24,714 per hectare and the average return to labour was Nu. 143/day, which were above the prevailing wage, rate.

In 1998, the market price of rice was Nu. 20/kg. And the results from the study showed cost of rice production for that year to be Nu. 13. 90/kg. It could be deduced from it that production of local rice was still more economic than purchasing it (a net difference of Nu. 6.10/kg). However, whether rice growing is really 'economic' can only be judged when its returns to land and its returns to labour with those for other crops or other farm enterprises or off-farm activities are compared. This remains to be done.

5.3.2 Economic Analysis of the Use of Sanbird to Control Shochum.

A study on the economic feasibility of the use of Sanbird to control Shochum was conducted in 1999. This study made use of secondary data from the annual CARD reports. According to these reports, studies done by researchers on weed control at the RNR-RC, Bajo from 1988-1991 identified Sanbird as one of the chemicals particularly effective in controlling all kinds of weeds including "shochum". However, this weedicide is expensive and has to be imported from Japan. Hence, this study was done with the objective to do an economic analysis by comparing all costs involved and benefits that accrue from the use of this herbicide.

The analytical procedure that is used for this study is the partial budgeting method. This method involves a comparison of only the extra costs and benefits that are involved in adopting a technology. A marginal analysis is also conducted. It indicates how much return from each net extra cost of Nu.1/ha the farmer is able to obtain.

Results of the trials from 1988-1991 show that plots treated with Sanbird yielded significantly more grain than the farmers' practice of handweeding. The average grain yield from Sanbird plots was 6.3 tons per hectare as compared to 4.5 tons per hectare from farmers' practice. However, it was noted that farmers' practice of weed control has changed over the years. Butachlor supplemented by one or two hand weedings is now the farmers' practice of controlling weed in the Punakha-Wangdue valley.

Table 34 illustrates total benefits gained and the total costs incurred yearly. The *added benefits + the saved costs* comprise the **total gain** while *the added costs + the benefits foregone* together make the **total costs**.

Table 34: Type of costs and benefits annually

Year	Costs		Benefits	
1-5	a. Added costs	Nu/ha	c. Saved costs	Nu/ha
	Sanbird	22750	Butachlor	645
	Labour to apply Sanbird	270	Labour to apply Butachlor	270
			Labour for hand weeding	3443
	b. Benefits foregone		d. Added benefits	
			Extra rice yield	18,000
			Extra Straw	2,000
Total		23020		24358
6-10	a. Added costs		c. Saved costs	
	Sanbird	0	Butachlor	0
	Labour to apply Sanbird	0	Labour to apply Butachlor	0
			3. Labour for hand weeding	0
	b. Benefits foregone		d. Added benefits	
			Extra rice yield	18,000
			Extra Straw	2,000
Total		0		20,000

The annual added costs of applying Sanbird from year 1-5 were Nu. 23020/ha and the benefits accrued from it was Nu. 24,358/ha. Applying Sanbird increased gross benefits by Nu. 24,358/ha. Increase in rice yield contributed a major per cent of the benefits. With Sanbird application labour for handweeding was reduced by about 75% or by Nu. 3443. It was assumed that shochum is totally eradicated after the fifth year and application of Sanbird is discontinued from the sixth year. Farmers will then resort back to their own practice of weed control (Butachlor + 2 hand weedings) from the sixth year. But the benefits of increase in rice yield will last until the tenth year.

Table 35: Marginal rate of returns calculation showing the costs and benefits, net gain and marginal rate of return for Sanbird application (Nu /hectare).

a	*b*	*c*	*d*	*e*	*F*	*g*	*h*
Year	Added benefits & saved costs	Added costs & benefits foregone	Total net gain (*b-c*)	Discount factor (20%)	Discounted total net gain (*d*e*)	Discounted added costs & benefits foregone (*d*c*)	Marginal rate of return (*f/g*)
1	24358	23020	1338	0.833	1115	19183	6%
2	24358	23020	1338	0.694	929	15986	6%
3	24358	23020	1338	0.579	774	13322	6%
4	24358	23020	1338	0.482	645	11101	6%
5	24358	23020	1338	0.402	538	9251	6%
6	20000	0	20000	0.335	6698	0	-
7	20000	0	20000	0.279	5582	0	-
8	20000	0	20000	0.233	4651	0	-
9	20000	0	20000	0.194	3876	0	-
10	20000	0	20000	0.162	3230	0	-
Discounted total (Net present value)					28037	68843	41 % =28037 / 68843

The marginal rate of return (MRR) calculations for Sanbird application is presented in table 2. According to the assumed application schedule MRR is 41% which is not economically attractive because if a technology is new to the farmers and requires that they learn some new skills, a minimum of 100% MRR is recommended.

5.3.3 Crop Budgeting (Winter Crop)

Raw data of winter crops like mustard, wheat, fodder and potato has been collected from the Lingmuytey Chu watershed area. This data has been entered in into the MS EXCEL spreadsheet and shall be analysed.

5.3.4 Market Appraisal Study in Punakha Wangdue Valley

Survey on the market appraisal study in Punakha-Wangdue valley was conducted jointly with Agriculture Marketing Section and NRTI trainees in the month of April 2000. The main objectives of the study are to:
1. Design an overall guideline for undertake marketing survey in Bhutan agro and Social-Economical environment.
2. Identify marketing opportunities and constraints for farmers throughout Punakha-Wangdue valley.
3. Highlight the constraints and problems of vegetable marketing in the two Dzongkhags.
The survey covered six vegetable growing geogs from each Dzongkhag, which are at the lower altitude. Punakha and Wangdue Sunday markets are also covered. Development of spreadsheet form and data entry is proposed in July

2000, data analysis on August-September 2000, first draft by September 2000 and final report and presentation by October 2000.

5.3.5 RNR Data Survey Validation

RNR data collected from the five Regional Dzongkhags i.e. Gasa, Punakha, Wangdue, Dana and Tsirang are entered in the zip by the data manager at the Dzongkhag level and 20% of the data are send to the RNRRC for validation. The 20% data are validated by the economic section and submitted to PPD for further validation and final report. This shall continue in the following years too.

5.3.6 Weekly Price Data Collection from Sunday Market (Wangdue)

Price data of the commodities at Sunday market is collected weekly. The activity will continue in the coming year.

5.4 Water Management Research

5.4.1 Citrus Irrigation: *When, How much and H*ow?

Background

Citrus is an important cash crop for the farmers of the foothills and mid [1](1500 m) altitude regions in the country. The area under citrus in the country is estimated at 5000 ha. The average yield is estimated at 10 t/ha which is much lower than the optimum level. The bulk of the produce is exported to India and Bangladesh.

The citrus grown are of mandarin type, the common cultivars being Khasi orange[2] in south-eastern region and Darjeeling/Sikkim orange[3] in south-western region in the country. The main characteristics of Khasi orange are sweet taste, tight segments and thin peels whereas the main characteristics of Darjeeling/Sikkim orange are very sweet taste, loose segments and thick peels.

Citrus is grown with minimum production management. Nutrients, pests, diseases and water management are almost nil. It is mostly grown under rainfed condition with poor orchard sanitation. The orchards are developed mostly on marginal land with light soils where other forms of agriculture is difficult. Seed is the dominant source of planting material which has long gestation period before bearing fruit. Fruit fly, trunk borer and die back are some of the important pests and disease.

Integrated citrus orchard management is seen as potential to increase the present yield level as well as the quality of fruit. With the shift towards market economy, a move towards better management for better productivity has to be made.

Soil Moisture Regimes

A trial to study soil moisture regimes as time series data was required as the base-line information to plan water management activities. The trial was started in November 1998 in Gelephu and Tingtibi in collaboration with RNRRC, Jakar. The main objective of the trial was to gather information on soil moisture regimes as a function of time. The time series soil moisture data was to be compared with the annual development cycle of the tree to find out the critical water stress periods. Knowing the soil moisture regimes and the critical water stress periods, supplementary irrigation requirement was to be estimated.

Two sites each in Tingtibi and Gelephu with four replications under each site are under observation. Each replication has two trees, one with mulching and the

[1] South facing slope, otherwise up to 1200 m

[2] International Symposium on Citriculture, November 23-27, N. R. C. for Citrus, Nagpur

[3] International Symposium on Citriculture, November 23-27, N. R.. C. for Citrus, Nagpur

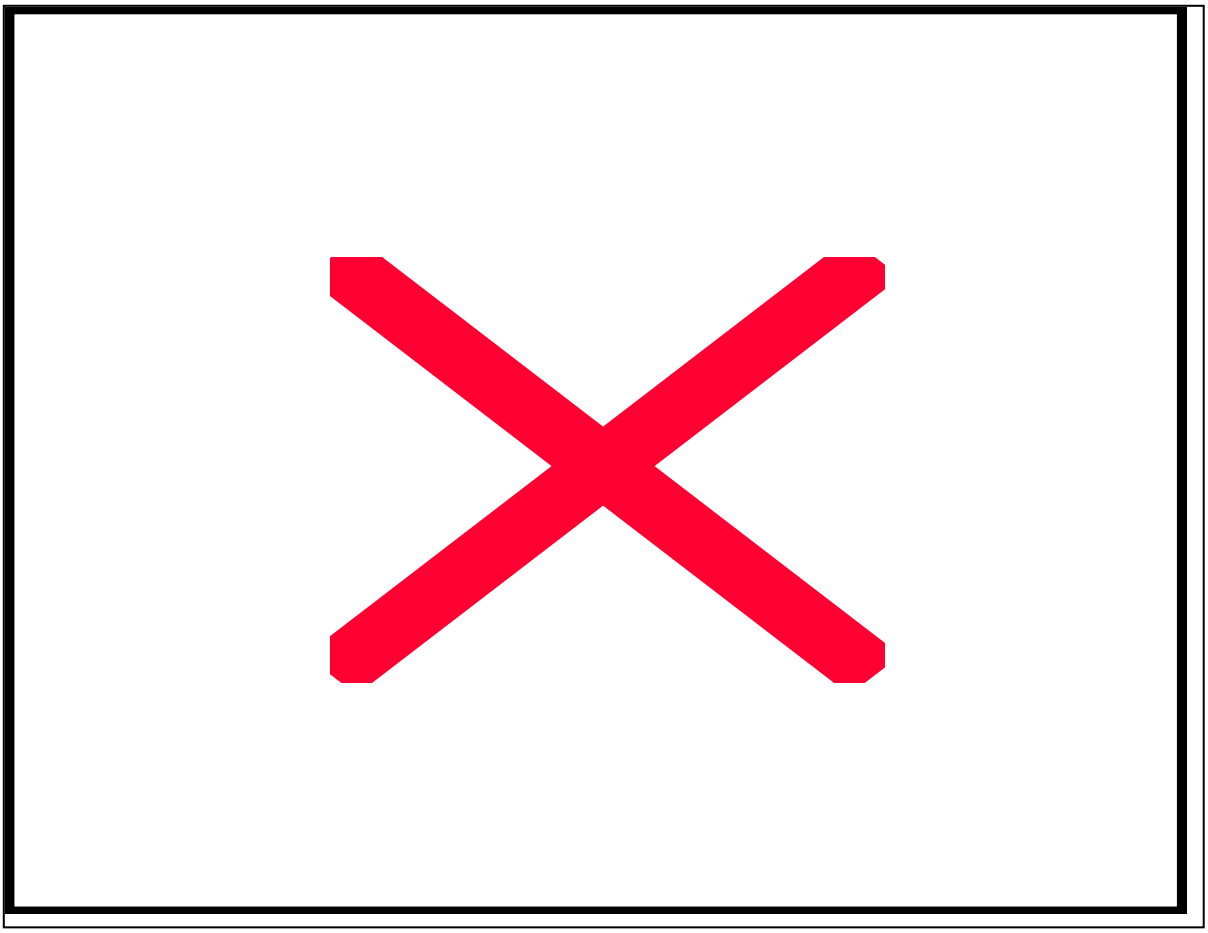


Figure 7 : Soil moisture data with annual development cycle from Dakpai (Altitude: 1060 m & Annual Rainfall 1574 mm 1999 data only) on 30/10/1999, Zhemgang. [*M: 10-15 cm mulching, NM: No mulching*]

other without it. Under each tree, three gypsum blocks are buried at 30 cm, 60 cm and 90 cm depth in the soil. In each site a rain gauge is installed. The soil moisture and rainfall readings are recorded on every third day. The annual development cycle is also recorded. The soil moisture data along with the annual growth cycle is presented in Fig.7.

Findings

The time series soil moisture regimes show (refer to Figure 8) that citrus is water stressed during critical annual development stages of awakening, flowering, flushing, fruit setting and
initial fruit enlargement periods corresponding to February-March to May-June. Flowering is observed by early March and fruit setting is over by April. But the onset of flowering and subsequent fruit setting is determined by the moisture condition of the soil. Under deficient soil moisture condition, flowering is observed as late as early April. For the later part of fruit enlargement stage from June till the ripening stage in September the moisture is sufficiently provided by the

rainfall. As the fruit matures and till it is harvested in November/December, the depleting soil moisture matches the lesser water requirement for better TSS.
The soil starts drying up by late September to early October. The soil becomes dry (>100 centibar) down to a depth of 90 cm by December. It remains generally dry till May/June, except for isolated wetting of topsoil due to North-East and pre-monsoon showers. The soil moisture tension returns to optimal (20~30 centibar) level by early May in the southern foothills and by mid June in higher altitudes (mid hills) with the arrival of the monsoon.

The citrus growing regions receive annual rainfall ranging from 1000-50000 mm which is sufficient to provide the moisture requirement. But, Bhutan has a unimodal rainfall distribution brought by the South-West Monsoon 80% of which is concentrated between June to October. The North-East Monsoon is limited to a few rainfall events which occur between December to March. This rainfall (winter/spring) in most years is not sufficient to provide the moisture requirement for optimum fruit yield and quality. Supplementary irrigation during few months of the critical water stress period has the potential to increase the yield and the quality of the fruit.

Irrigation Scheduling: When to irrigate?

Judging by the time series soil moisture regimes and comparing it with the annual development cycle of citrus, supplementary irrigation is required from mid February till end of May (Refer to Fig.8). Harvesting is completed by November-December. January to mid February may be the stress period required (natural moisture stress) to induce better flowering and flushing. Moisture stress for about a month or two is absolutely necessary for citrus to induce better flowering and flushing. Numerous studies have been done to find out the causes of irregular flowering in citrus. It is found that citrus has to be stressed either through low temperature (cold stress) or soil water deficit stress (moisture stress) to induce better flowering and flushing. Sometimes use of growth retarding chemical to stop the vegetative growth (in case of constant moisture supply from sub-surface layers) has been successful in inducing good floral response. Application of Paclobutrazol @ 18g/plant at the time of imposition of moisture stress was found effective. In warm regions low temperature is not enough to stress the plant. In such situations moisture stress is a better option. The success of moisture stress is dependent on the nature of surface and sub-surface soils. The soil properties such as high clay content, mainly concentrated in sub-surface soil was found conducive for irregular flowering. High clay content impede drainage and has higher water holding capacity which account for lesser moisture depletion during moisture stress period, with the result, the required quantum of stress is seldom attained and plants flower erratically[4].

[4] Research findings as reported in National Research Centre for Citrus: At a glance

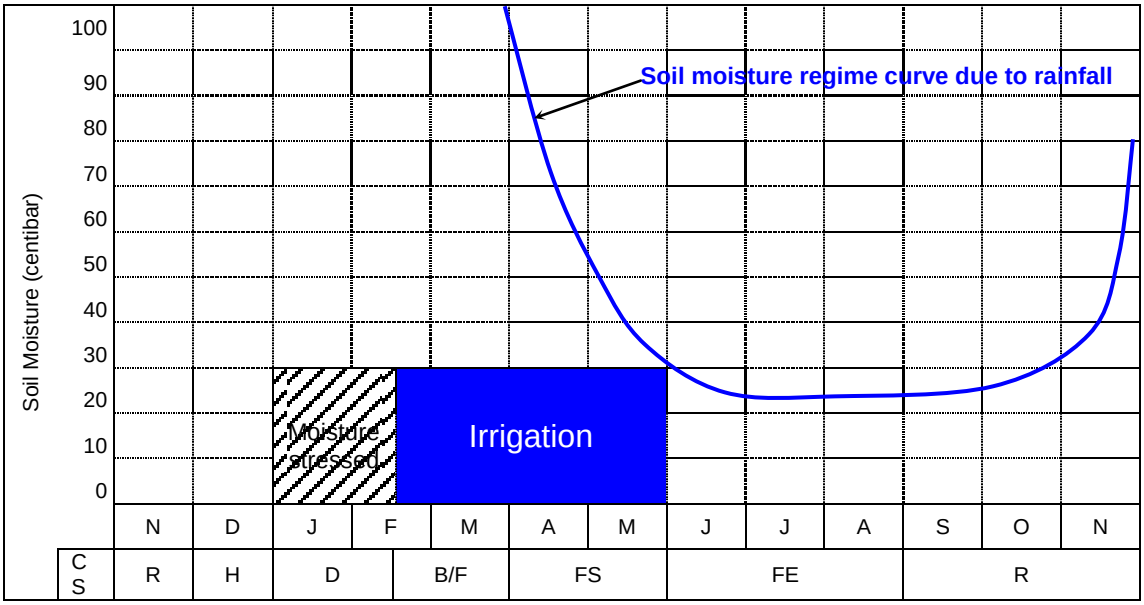


Figure 8: Irrigation scheduling with respect to development stage of citrus [R: *Ripening,* H: *Harvesting,* D: *Dormant stage,* B: *Budding,* F: *Flowering,* FS: *Fruit setting, and* FE: *Fruit enlargement,* CS: *Crop Stage*]

Scheduling irrigation (water management) for citrus requires good data on the local conditions with respect to rainfall and development stages. Giving water at the wrong time will have a great impact on the fruiting. Over irrigation is also harmful. Timing of irrigation coinciding with the critical growth stages is very important. Stopping irrigation for one to two months after harvest to stress the plant is absolutely necessary.

Water Requirement: How much water to give?

Citrus is more of a xerophyte which has adapted well to dry and hot climate. Its oily leaf is an adaptation to control excessive evapotranspiration. Mature citrus trees require from 1000 mm (Koo,1963) to 1563 mm(Van Bravel *et al*., 1967) of water a year to replace that lost by evpotranspiration. For citrus ET_{crop} is always less than potential ET and it is not more than 80% (Davies and Albrigo, 1994). Several studies have been conducted comparing citrus yields at various pan evaporation levels. In Israel no difference in yields of 'Valencia' orange trees was found at 35, 47.5 or 60% of pan evaporation (Yager, 1977). Daily water replacement of 5 mm at peak season for established orchards is given in Israel. For young trees daily water use of 3.5 mm is provided. These daily water use figures are computed using an irrigation factor of 0.5 - 0.6 for ET_o determined under the Israeli climatic conditions. Suppose ET_o was calculated to be 10 mm/day, actual water application will be 5-6 mm/day.

During the critical water stress period from February to May, the water requirement of citrus in the foothills (of Bhutan) is expected to be more or less equal to the Israeli figures. In higher altitudes it will be less. Without reliable climatic data, it is difficult to calculate the water requirement of citrus. Irrigating using soil moisture status will be a good alternative. Tensiometer readings give

reliable soil moisture status. Quantity and interval of irrigation can be adjusted to suit our conditions. Tensiometer can normally read up 100 centibars (1bar) suction or soil moisture tension. For most soil types, 0 centibar indicates saturated condition, at 10-20 centibars the soil is at field capacity. For most tree crops (especially citrus) , 20-50 centibars is sufficient to supply the moisture requirement. At 60-70 centibar and above, irrigation is required.

As citrus is mostly grown on light soils, a good practice would be more frequent irrigation with less water at a time. More water at one time and less frequent irrigation would result in percolation beyond the root zone and water stress before the next irrigation turn. As a thumb rule the irrigation interval should not be more than 7 days. Keep record of the quantity of water given and the interval between irrigation. Observe the tensiometer reading and the soil moisture condition. Observe the leaves for signs of wilting. Adjust the quantity per irrigation and the interval of irrigation

Method of Irrigation: How to irrigate?

Citrus can be irrigated by various methods like basin, sprinkler or drip irrigation. By what method we irrigate is determined by the resources available; sprinkler and drip are expensive while basin irrigation is comparatively cheap.

Basin irrigation of citrus is an appropriate method for our farmers. The investment required is not very high and if done with good control over water, it could be an effective method. A basin of appropriate diameter around the tree is made. For a normal bearing tree a basin of 1.5 to 2.5 m diameter would be sufficient. The water is given to the basin by a ditch or a hose pipe and allowed to infiltrate the soil. Care should be taken not to wet the trunk directly; raised soil is kept around the trunk of the tree.

Some farmers let the water run down the slope of the orchard. This is not a good practice especially if the orchard is on sloping land. The surface flow without much infiltration would lead to soil erosion. A good substitute for this method would be irrigation by contour ditches; a contour ditch above the line of trees should be filled with water and let it infiltrate the soil.

5.4.2 Water Distribution and Sharing in Lingmuteychhu Watershed

Background

Farmers' water management practices was studied as a component of the Water Balance Study in the Lingmuteychhu Watershed. The objective of this component was to study the farmers' water management practices and how they relate to efficiency of water use and water shortage. The study has covered three broad issues of (i) water distribution and sharing at the watershed level (inter-community), (ii) water distribution and sharing within community (intra-community), and (iii) farmers' water management practices. The study and the findings are explicitly for paddy cultivation which is their main crop.
The Lingmuteychhu Watershed extends from 1200 m on the right bank of the Puna-Tsangchhu to 2600 m at the top of Shengana La, Antakarchu and Darchula

ranges. The watershed has an area of 34 km^2. The watershed supports 175 households distributed in seven villages. Agriculture is the main source of livelihood and wetland based farming activities contribute the major part of it.

Methodology

The information on farmers' water management practices was gathered through intensive field studies with interaction with farmers. The study team camped at site for more than a month each on two transplanting seasons. There was no structured questionnaires for interaction with the farmers. Information was collected by asking farmers on "why they do what they do". "What they do" was directly observed by the study team as the farmers managed their irrigation systems. Once trust building was done and a good rapport was established, information flow was easy.

The information given by the farmers was cross-checked with the field operational activities. The information was refined through successive formal and informal meetings with many farmers. When there was disagreement over certain information among the farmers, further verification was done with farmers who know the situation better and field verification was carried out. The communication channel has been open for the last three years and we interact whenever there is need for it.

The water used for land preparation was measured in farmers' test fields with the use of flumes. The daily consumptive water use was measured with slant gauges. The standing water maintained in the terraces after the transplanting was observed and recorded.

Findings

Lingmuteychhu (or Limtichhu in short) is a small stream which drains the watershed. It comes out of a rock face as a spring above the village of Lingmukha at about 2300 m above sea level. It is not fed by any glacier and therefore the flow is totally dependent on rainfall. Shenzarongchhu which drains the Darchula range of the watershed joins it at about 1800 m above sea level as a left bank tributary. It has a length of 11 km at its confluence with Puna-Tsangchhu. The general slope of the river is 1:10.

The base flow during the driest months in April/May fluctuates about 40-50 l/s. The flow after a wide spread rain in the watershed can be more than 500 l/s. The stream can be termed as an ephemeral stream. The rainfall-runoff response is quick and it returns to the base flow within a couple of days after the rainfall. The flashy nature of the stream is due to steep gradient of the watershed.

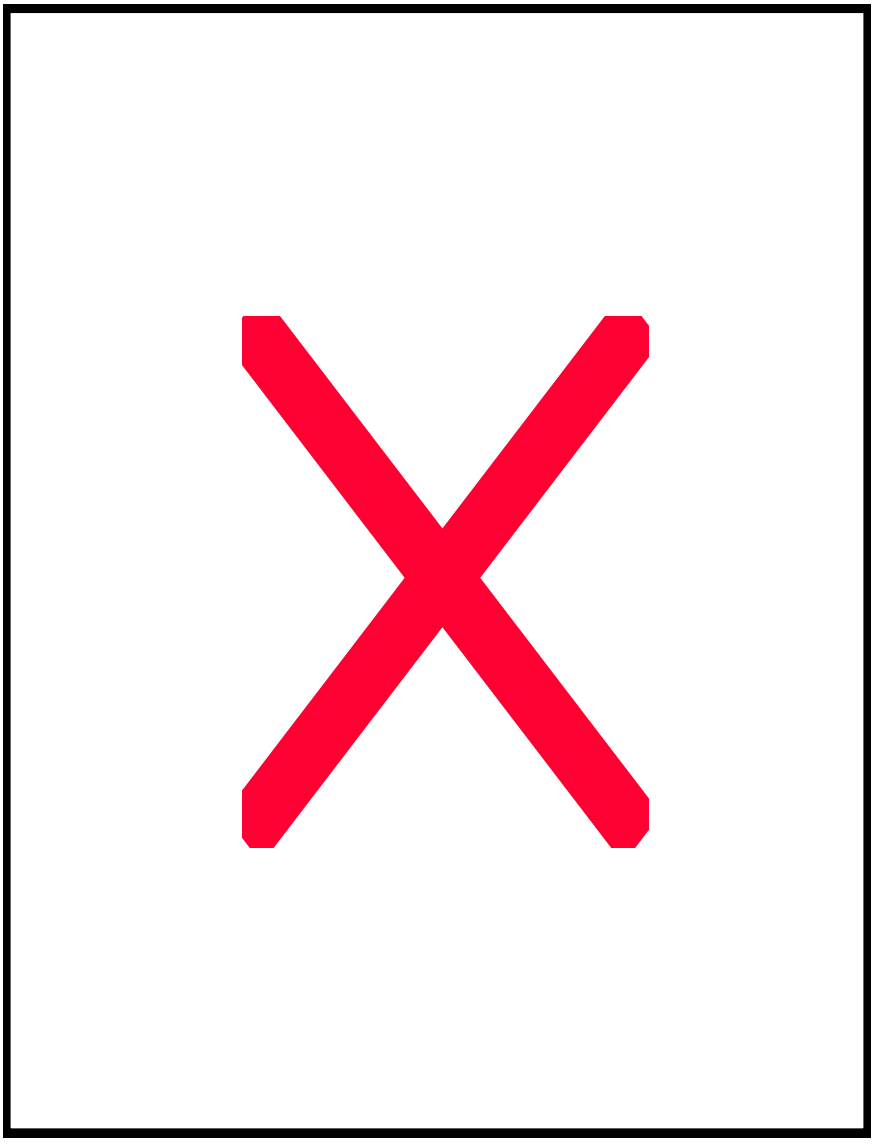
Existing irrigation infrastructures

The watershed has five irrigation systems formed by 12 irrigation canals that irrigate about 200 ha of terraced wetland. 11 irrigation canals share the same source while one irrigation canal brings water from another watershed (refer to

Fig. 2). The Nabchhe village is predominantly under dryland system and a few minor irrigation ditches that exist are not included in this study.

The Lingmukha Irrigation System is formed by Jabsakha, Baryuwa, Maryuwa and Dompola irrigation canals (see diagram below). The Dompola and Omtekha Irrigation Systems are formed by Dompola and Omtekha irrigation canals respectively. The Matalumchu Irrigation System is formed by Sechuyuwa, Tagtayuwa, Baryuwa, Tongyuwa, Geyuwa and Dogangjo irrigation canals. The Wangjokha/Thangu Irrigation System is formed by Bajo irrigation canal which draws its water from Pechu in another watershed. The water from Limtichhu is available to Bajo canal only when there is surplus water flowing down from the watershed during peak monsoon period.

All the irrigation canals are small-scale irrigation schemes. Major sections are earthen canals and masonry lining is done only in seepage prone sections. Pipes and mild steel channels are used in crossing gullies. The intakes are temporary



structures made of stones and brush wood.

Water Distribution and sharing at the watershed level

The water abstraction by different irrigation schemes from the same source is based on two broad rules. The first rule of water abstraction at the watershed level is "first come first served". It means that existing schemes have an established water right and can prevent new comers from using the water if this is at the disadvantage of the existing users. The community at Nabche are the late settlers in the watershed and they do not have water rights to construct an irrigation canal. The second rule may be interpreted as "more access to water to communities near water or higher in the watershed". Communities near the water exercise more control over it. The Lingmukha community controls the head water since they are at the top of the watershed. They use water as much as they want, sometimes in excess, ignoring needs of the downstream communities. The communities higher in the watershed divert the whole flow in the stream into their irrigation canals and lower communities depend on seepage or the residual discharge.. By an established rule, the Dompola community gets half the flow in the stream only from the10th day of the 5th Bhutanese month every year. In 1997 it was on 16 June while in 1998 it was 4 July. Even after this date, Lingmukha people still use the water to irrigate their land under the command area of Dompola irrigation canal. The Omtekha community diverts the whole flow in the stream into the Omtekha irrigation canal. Matalumchu community immediately downstream has to depend on the seepage for their water need. A few years ago, Omtekha irrigation canal secured government assistance to line the canal. The lower community filed a court case contesting the decision to line the canal. They pointed out that lining the Omtekha irrigation canal would deprive them of their water need since they depended on the seepage from it. The court ruled that Omtekha canal should be lined in sections agreed by the Matalumchu community upholding the status quo principle.

Water distribution and sharing at community level

All the Irrigation Systems serving a community have their own on-farm water distribution practices with well defined rules. There are similarities while some are unique to themselves. But the single pattern that emerges is that it is neither based proportionately on wetland area nor distributed equally among all households. Water is distributed by rotation. The water rights at household level is passed down from generations and it has evolved over a long period of time. In some sharing system the water rights is connected to contributions to communal religious ceremonies. In others water share is associated with labor contribution during construction and renovation of the canals.

Lingmukha Irrigation System

Lingmukha is the top most village in the watershed where water is in abundance. Before the 10th day of the 5th Bhutanese month water is distributed on need or request basis. The users who have gathered at the intake who need water on a particular day decide it. Preference is given to water required for soaking the field before land preparation, soaking the nurseries for uprooting the seedlings and for land preparation. If water is available it is given for topping the transplanted fields
.

After the 10th day of the 5th Bhutanese month a formal rotation schedule comes into effect. It is a three day rotation pattern during which four relative water share categories distribute water. The four relative water share categories are "thruelpa", "chhep", "chatho" and "lhangchu". These categories share water according to the quantity of flow on that particular day. The "thruelpa" gets half the flow in the channel while the "chhep" gets half of "thruelpa" and "chatho" gets half of "chhep". The last category has to beg the community to adjust and give him/her water normally at the convenience of the community. This category as the name suggests (lhangchu = beg water) has no formal water right. The Lingmukha farmers who have land under the Dompola irrigation do not follow this rotation pattern. They use water as and when they need it.

According to the water users, the water share is related to contribution to two annual communal religious ceremonies. One of them is performed at the water source for good water yield. In principle the water share can change with the change in contribution, but this has not happened in practice. 17 households have "thruelpa" water share while 8 households are "chhep" category. The "chatho" and "langchu" categories consist of 4 households each.

Dompola Irrigation System

A strict rotation system is practised as soon as they get the water. Here the relative water share is as same as in Lingmukha but they do not have the last category. After the renovation of the channel in 1998 the farmers have changed their water distribution system. They have made it more rational based on the wetland acreage. The labor contribution for the renovation work was also done based on the wetland acreage. Even the annual maintenance labor is based on land area. With the new system, the rotation interval has been reduced to 4 days from 5 days. The rotation starts with the user group in which the Yupen (water guard) is a member. The new system assumes that the flow in the channel will irrigate 40 langdoh of wetland in 24 hours. The basic principle is all users whose wetland area sum up to 40 langdoh will share the flow of 24 hours. A farmer who has 20 langdoh takes half the flow in the channel and the rest of the users on that particular day share the other half as per their land holding size making the other 20 langdoh. There are four water user groups of 6, 5, 10 and 8 farmers. The members of each user group are scattered from the head and tail end of the command area. This is devised by the farmers to avoid the lag time in getting the water. If the whole flow was in one area, it takes considerable time for the water to reach the next area. This has some problem when the 24 hour rotation begins at 6 pm.

Omtekha Irrigation System

The water is supplied to the command area by 8 secondary channels. Which secondary channels start the rotation is decided by secret ballot. The rotation pattern is unique in the sense that they have two rotation intervals. The first category get water on every sixth day and the second category, the "wueche" get water on the 13th day; after the first category received two times. The first category are the descendant of the builders of the canal. The second category are the newcomers who settled at the tail end of the command area. This category do not contribute labor to the annual maintenance of the canal. However, they pay an annual sum of Nu. 30-50 to the first category of water users.

The water rights among the first category is varied. The 24 hour flow is shared by groups of users ranging from 1-5 users. In the past the first category water users consisted of 6 households when each household was entitled to full flow in the canal for 24 hours. Over the years the five households have subdivided their land and with it the water right. Only one household has been able to maintain the original water right.

The following figure illustrates the water rights and the rotation interval. The letters A-V represent the households using the water. There are 6 households (I, D, B, H, F, E) who get half the flow for 24 hours. There are 4 households (U, M, K, G) who get one-eighth of the flow for 24 hours. There are 2 households (T, L) who get one-fourth of the flow for 24 hours. The single household (C) gets the full flow for 24 hours. All the "wueche" households (V, R, Q, P, N) get one-fifth of the flow for 24 hours.

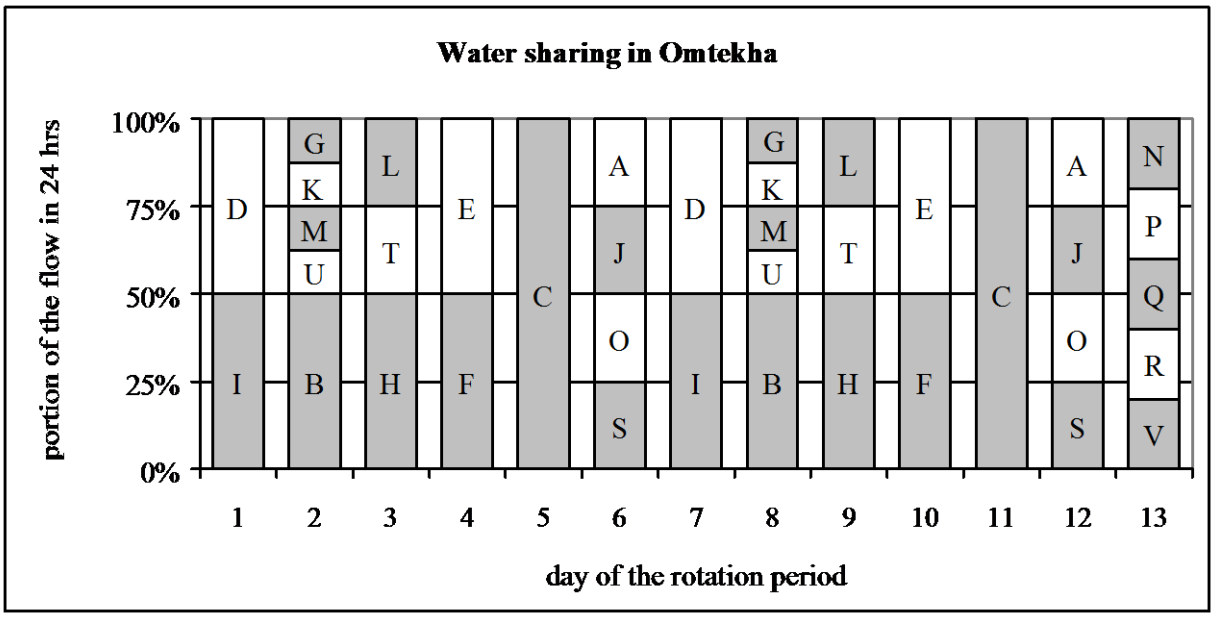


Figure 9: Water sharing scheme diagram (Omtekha)

Matalumchu Irrigation System

The Matalumchu Irrigation System is made up of six irrigation canals, three canals on each bank of the Limtichhu. Rotation for water starts from the left bank irrigation canals. The command area of the left bank irrigation canals is under local red rice varieties which requires early transplanting. Transplanting is started by mid May. The right bank irrigation canals are activated only after transplanting on the left bank is more or less over. The area under the right bank irrigation canals are mostly under improved or local white varieties.

The water right is equal among all the households irrespective of their wetland area. 21 households share the water with a rotation interval of 7 days. 3 households share the water for 24 hours. The 3 households who share the water adjust the flow among them according to their wetland area. Normally they share equally for flooding the fields during the night and adjust the flow in the morning according to need depending on the level of water in the field for land preparation. There is an in-built mechanism to bring flexibility in the sharing system. The three member group are reshuffled every year before the transplanting season. The regrouping is done through secret ballot. All the water users have to understand each other's problems and be accommodating to each other. If one is not flexible in sharing water, he/she runs greater risk in the next season since he/she does not know who will be his/her partners.

Wangjokha and Thanghu Irrigation System

Wangjokha and Thanghu villages are located in the lowest part of the watershed. During the transplanting season the farmers entirely depend on the Bajo irrigation

canal which brings water from another watershed. During this period the flow in the Limtichhu does not reach the intake point of the Bajo irrigation canal. After the monsoon is at its peak by end of July to mid August, the flow is sufficient to cater to the Bajo irrigation canal.

The Wangdue town and the Military Training Centre to supplement their drinking water supply use the Bajo irrigation canal. It also is the source for the irrigation requirement of the Renewable Natural Resources Research Centre (RNRRC) and the Bajo community. The town and the training centre always take a certain percentage of the flow. The discharge given to the RNRRC is defined as the flow from a 3 by 3 inch opening in the side of the canal above the research centre. The research centre is entitled to a day's/night's full flow within the rotation system in addition to the continuos flow. Unlike in the other water rotation systems, here the rotation period is for 12 hours, night and day irrigation. The rotation starts at 6 o'clock in the morning and ends at 6 o'clock in the evening. The chart below describes the day-night rotation among three user groups.

day	Day turn	Night turn
1	Bajo	Wangjokha & Thanghu
2		
3		
4		
5		
6	RNRRC	Bajo
7	Wangjokha & Thanghu	
8		
9		
10		
11		RNRRC

Figure 10: Day night rota for water user groups

During the first 5 days Bajo community get the flow during the days while Wangjokha and Thanghu take the night turn. On the sixth day RNRRC gets the days flow. The next five days Wangjokha & Thanghu will take the day turn while Bajo will irrigate during the night.

In Wangjokha & Thanghu water is distributed according to wetland acreage. The flow during the 12 hour is considered to be enough to irrigate 80 langdoh. The main households are put into five groups with 80 langdoh each. Each group can consist of a single household or a few related households who have broken away from the main household. The chart given below illustrates the water right or share at household level:

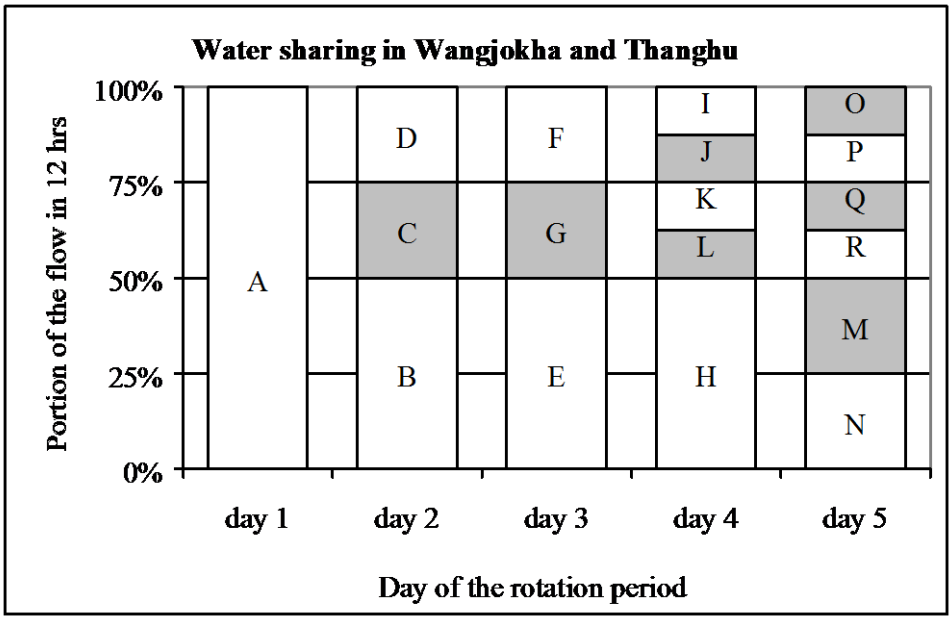


Figure 11: Watersharing in Wanjokha and Thangu

After every five days a group of households share the 12 hour flow in the canal according to their wetland size. There is a household who gets the whole flow for 12 hours. There are three households who get half the 12-hour flow. There are six households who get one-fourth of the 12 hour flow. There are eight households who get one-eighth of the 12 hour flow.

The “lending” and “taking” of water bring a degree of flexibility in all the distribution systems. It is an internal arrangement in the rotation system whereby two sharing partners agree to "lend" and "take" each other's share of water in a particular rotation period. This practice does not affect the overall rotation system but the two partners' irrigation interval in the next rotation will double. The "lending" is normally practised when the flow in the channel is not enough to cater to all the users or the labour shortage forces a farmer to lend his share.

Farmer’s water management practices

Farmers' water management practices can be described by excess use of water. Their basic concept of water management for rice is "more water means higher yield". It is derived from the traditional Bhutanese proverb which loosely translates to "paddy has to be nurtured and matured by water" (Jha Chugi Pho Jhago). The water use for land preparation for transplanting ranges from 133 mm to 472 mm. The water use for land preparation in the upper areas of the watershed especially in Lingmukha is much higher in comparison to international (FAO) water requirement figure. Here the land is soaked for about 5 days with a small continuous flow. It is to rot all the shrubs and to break down the clods. According to the farmers, soaking makes land preparation easier and improves water retention in the field. Water use decreases as we move down the

watershed but the quantity is still higher than the FAO figure. Farmers lower in the watershed cannot afford the same practice as in Lingmukha. Here they soak over night and next morning they have to puddle and transplant. By evening, water will go to the next group of farmers.
The daily consumptive water use ranges from 13 mm to 42 mm. The soil types mostly determine this figure since its major component is infiltration loss. Farmers always try to maintain about 100-120 mm of standing water in paddy terraces. This depth is maintained by a small continuous flow from terrace to terrace. In most cases there is an overflow from the last terrace. A constant effort to top the field is made so that the standing water is replenished. The safety outlets from terrace to terrace and from the last terrace is more or less at the same level as the water level in the field. And therefore heavy rainfall results in overflow and slumping of the bunds. Nutrient outflow and leaching is expected to be substantial. Another bad effect of constant standing water is the proliferation of aquatic weeds (potamegeton spp.). The weed spreads at the surface of water competing for nutrients and blocking sunlight. It also physically chokes the hills and inhibits tillering.

Under the existing water rights and the distribution systems which have evolved over a long period of time the resource use efficiency is low. There are inter and intra community conflicts over water. Equity principles have been sacrificed in the process of evolution of the water rights in the past. Farmers' water management concept and practices have to be changed and geared towards meeting crop water requirement. Legal framework and institutional capacity development in water distribution and management have to be initiated.

5.5 INTEGRATED PEST MANAGEMENT

5.5.1 Farmer Field School (FFS) Experience in Phobjikha

Introduction

Since the inception of FFS in 1999, the integrated disease management (IDM) of potato via the FFS approach is currently in its second year, in Phobjikha under Wangdue Phodrang Dzongkhag. One of the major potato diseases that affects potato production is late blight (LB) caused by fungus *Phytopthora infestans* which is still the number one constraint in the chief potato producing areas such as Phobjikha, Bumthang, Chapcha and some parts in eastern Bhutan. Although Bhutan currently grows about 5654 hectares of potato in the temperate regions with yield ranges of 15-25 tha^{-1} (Nidup, 1999), potential to increase the yield does seem possible provided proper disease management is carried out in combination with recommended management practices. Sharing experiences from other countries in potato production recommendations have been made available on how to contain major pest and diseases. Yet our farmers have not completely adopted these recommendations. Hence to let the farmers have a first hand experience, the FFS approach which has been successfully executed in South East Asian countries was continued in Phobjikha with seven new farmers in addition to three farmers who had participated in the 1999 potato growing season.

Objectives

The short-term objectives are to assess the constraints in potato production; to induce the farmers in implementation of the best available IDM packages through FFS approach; to develop and test FFS curriculum on potato IDM; and to determine the out come effect and impact of IDM through FFS.

The long-term objective is to guide the farmers in discovering Integrated Pest Management (IPM) methods and build their skills and decision-making capacity in the control of potato pests and diseases.

Methodology

This year the FFS was carried out in Damchulakha (2820m), Tsokopangna (2840m), Yuesa (2890m), Tabading (2865m), Mole (2850m) and Dangsa (2840) villages under Phobji geog. These villages have reported incidences of late blight problems and among others soil borne diseases such as common scab.

Farmer and Site selection

The IPM research team from RNRRC Bajo visited Phobjikha during the first week of March 2000 and convened an informal meeting with the Phobji and Gangtey extension agents (EAs), Phobji Gup, Tshogpa and pre-identified farmers from the said geog. The three farmers who had participated in the FFS activity last season were present during the meeting who helped facilitate the discussion by relating their own experiences to the new farmers. During and after the meeting the

farmers were briefed on the objectives and procedures of the study and stressed on their participation and cooperation throughout the potato season. In all, more than 15 farmers had volunteered for the activity but a few of them could not assure the team of their participation throughout the season in view of labour shortage. The team in consultation with the concerned EA and village representatives agreed on 10 farmers including 3 who had participated in the last cropping season to be involved in the current FFS curriculum.

For the selection of FFS learning plots, the researchers and EAs in consultation with the concerned farmers visited the respective potato fields in each village and agreed on the site that was nearer to their residence. This was done as the farmers felt that it would be easier to monitor and guard against wild animals especially wild boars.

Learning plot design, treatments and planting activity

The EAs of Phobji and Gangtey geogs helped the concerned farmers to design the layout of the learning plots. However the farmers were encouraged in the making the layout on their own. In each village, 3 learning plots – each plot measuring 50 m^2- was laid out with the following treatments:

1. Good quality seed, recommended late blight control
2. Farmer seed, farmer management
3. Farmer seed, recommended late blight control

In each learning plot, potato variety *Desiree* was planted in the 3rd week of March 2000 as per the given treatments. Standard potato production practices were followed in all the learning plots.

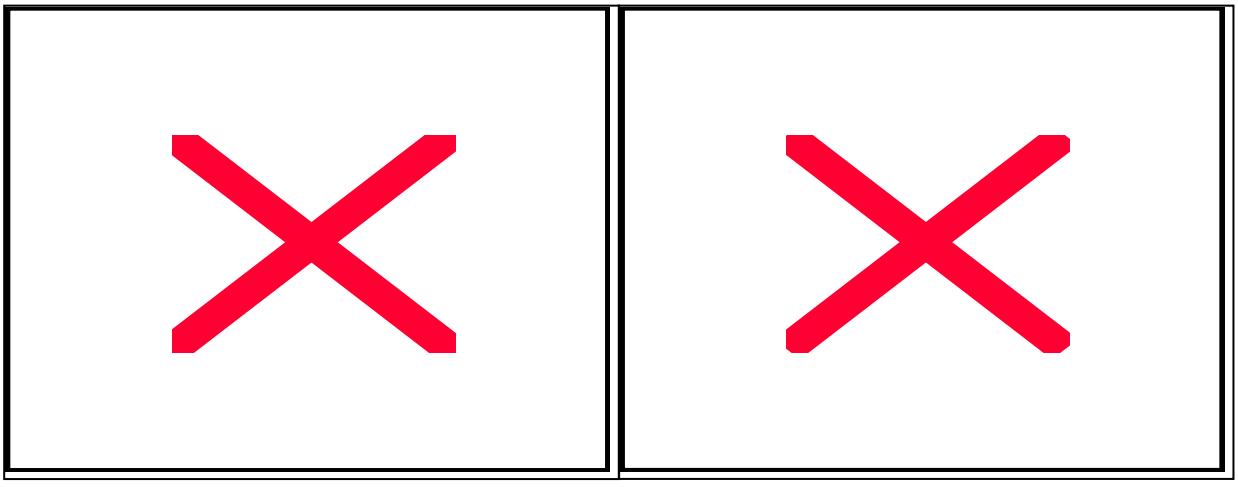


Figure 12: **EA demonstrating plant spacing**

Figure 13: **EAs selecting seeds for planting**

The farmers were also instructed on how to recognize and differentiate early blight from late blight symptoms in addition to the time and method of spraying fungicides such as Mancozeb and Copper Oxychloride in recommended doses. Among others they were also informed on the benefits of rouging volunteer plants

at the time of earthing-up and following proper plant spacing (figure 9a). However they were reminded that these factors would be compared against the farmers' management practice during harvest. Besides, the farmers were also provided hands-on training on the various aspects of potato production in addition to plant protection guidance throughout the cropping season. Sessions for different activity stages were also finalized with the collaborating farmers and procedures implemented as in Table 1, which also highlights what the researchers, and farmers learned at the end of the FF curriculum.

Results

Like last year the incidence of LB was very low this year also. Except in isolated cases LB occurrence was not very significant. Using the CIP scale, the LB scores were 1 in all the treatments (1=mild, 9=severe) at 60, 70, 80 and 90 days after planting (DAP). The yield from the treated plots did not vary significantly from the farmers' practice. The experiences gained at the end of the FFS curriculum is given in table 1.

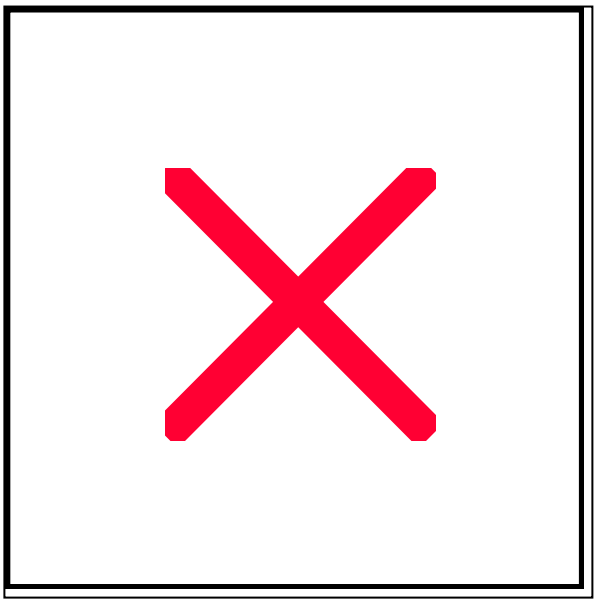


Figure 14: Farmers practising hilling up technology

Table 36: Implementataion plan and out put at the end of FFS activity

Session	Activity	Goal	What farmers learned	What researchers learned
Planting	Fertilization Planting space Seed selection Good quality seed	Farmers learn the importance of seed size use and its economic importance and planting space	Proper seed size selection and to avoid high density planting	Farmers use a combination of SSP, suphala and urea during planting. A handful of the mixture is applied for every *domgang* (approximately 2m) of rows. Some use only suphala preceded by farmyard manure (FYM) during land preparation.
Earthing up	Hilling up Roguing LB control	Farmers learn proper hilling and roguing and its importance	Proper hilling technology and roguing to remove volunteer plants. They understood that volunteer serve as source of inoculum for soil/tuber borne disease.	Most farmers do not practise roguing as they use volunteer tubers as vegetable during off-season.
Flowering	About LB and its control Roguing Virus diseases and other pests	Farmers learn about LB and its recommended control. They also learn about virus disease and other insect pests.	Learned to recognize LB symptoms in the field and how to control cutworm problems.	The farmers had been relying on toxic chemical such as furadan to control insect pests in the past, which has been banned now.
After flowering	Continuation about LB and its control Virus diseases	Farmers learn about LB and its recommended control. They also learn about virus disease and other insect pests.	Farmers learned when to spray mancozeb in addition to proper techniques of handling chemicals and equipment. They also understood that LB spores can overwinter in soil and that infected tubers serve as source of inoculum.	Farmers spend sleepless night guarding their crops from wild animals especially wild boar that come to feed on potatoes.
Harvesting	Result Tuber diseases Storage Data analysis Evaluation Planning	Evaluation and interpretation Plan for the next cropping season.	Farmers learned proper harvesting and handling techniques. They also learned the concept of crop cut and make comparative yield study.	Farmers preference for *Desiree* varieties as they fetch high prices compared to *Yukap* and *Kufri Jyoti.*

Conclusions

Though FFS approach has been successful in other countries especially in South East Asian countries, its success in Bhutan still remains to be seen. The following suggestions to popularize this diagnostic tool seem timely.

To spearhead this curriculum, a need for an in-country training for the FFS trainers by a TA specialist is felt necessary in view of the current researchers who have no formal knowledge on the subject.

In order to produce impact-oriented results the trained trainers should create greater understanding on the part of the EAs and farmers in particular through group discussions, hands on training and demonstrations.

Farmers in Phobji geog and surrounding villages have shown keen interest in continuing this activity. As such allowance for new farmers joining the curriculum have been prioritized.

***Parthenium hysterophorus* L.**

Local Names: Congress grass/weed or Parthenium weed (English)

Characteristics: Annual or biennial, erect to 1m. foliage dull grey-green, rather like *Artemisia* in seedling stage but not aromatic. Flowers are many in diffuse panicles, about 2 mm across with white disc-florets (no ray-florets).

Propagation: Being a prolific seed producer it is extensively spread because the seeds are light, armed with pappus that facilitates its dispersal through natural agencies such as wind, water, animals including humans.

Distribution: This is mainly a weed of roadsides and waste places but can occur in perennial crops. It was introduced in India from Central America and most probably introduced in Bhutan via India. This is a dryland weed at lower altitudes, mainly below 1200m, but occasionally to 1700m. In Bhutan it is found along roadsides and on wastelands in Trashigang, Monggar, Trongsa, Zhemgang, Punakha, Wangdue Phodrang and Thimphu.

In Wangdue Phodrang it was first observed near the Sunday market. Today it has spread rapidly from there to the surroundings of RNRRC-Bajo and as far as Taksa in the south. It can also be seen along the Lobesa roadsides.

Potential danger: A noxious weed in parts of India where it causes severe allergic illness in adult males, including those whose only contact is with pollen. It has been shown to be allelopathic and appears in places to be replacing *Artemisia* spp. And other weeds on roadsides.

Control/Management: It may be pulled or hoed at least thrice a year before it flowers, but contact with skin should be minimized, which can be done using hand gloves. Biological management methods are being introduced in some parts of the world. In India the National Research Centre for Weed Science at Maharajpur, Madhya Pradesh have found *Zygogramma bicolorata* a defoliating beetle, spraying of pathogen *Gliocladium virens* qith 5% neem oil, Marigold plant at 1:2 and 1:4 (Parthenium:Marigold) ratio to be effectively suppressing the growth and spread of *Parthenium* weed. Chemical control of this weed is achieved with the use of Glyphosate but its use over large areas can be uneconomical, non-sustainable and environmentally undesirable.

5.5.2 Farmer Study Tour To Paro On Control Of Shochum

Introduction

A 2-day farmer study tour was conducted by RNRRC, Bajo to Paro with the the objectuve to foster direct interaction between farmers of Wangdue and Lingmuteychu Watershed, with the farmers of Paro on the management of a noxious weed in rice, which is locally called as Shochum or Shoum *(Potamogeton distinctus).*

And also as part of the on-going campaign for intensive hand weeding to control Shochum.

The 24 selected farmers came from Wangdue and Lingmuteychhu Watershed with 16 farmers from 6 Geogs of Wangdue - Thetsho, Upper Gaselo, Lower Gaselo, Nisho, Kazhi and Phangyul; 8 farmers from 6 villages of Lingmuteychhu Watershed - Lingmukha, Dompola, Omteykha, Matalungchhu, Wangjukha and Thangu. The farmers were escorted by one extension Officer from Wangdue Dzongkhag, 3 researchers and Asstt. EPO from RNRRC Bajo. The team visited four Geogs of Paro Dzongkhag - Shari, Lango, Tsento and Shaba, where the farmers exchanged views with each other and discussed on the intensive hand weeding of Shochum vis-à-vis its advantages and other management practices.

Observations

Shari geog

1. Butachlor' applied twice once during line preparation and other during first 2-3 weeks after transplanting in Shochum severe area.
2. Control of Shochum through water management was also attempted; however this has further aggravated the Shochum growth according to the farmers of Shari.
3. Shochum after being uprooted is heaped on a terrace. EM (effective micro-organism) solution is then applied on weeded Shochum, which enhances decomposition. The decomposed Shochum is used in the chilly field as manure.
4. Chemical control of Shochum via use of herbicides like SANBIRD and NC 311 were attempted but the leaves portion dry once only; the following season the control is more visible.
5. Intensive weeding of Shochum had increased production by as much as 50%. Earlier a farmer used to harvest 1200 *dreys* of paddy from an acre of land compared to current harvest of 2400 *dreys* of Paddy subsequent to eradication of Shochum from their field.
6. Thorough hand weeding was practised by selecting few pocket areas having heavy Shochum infestation by removing the rhizomes, and simple weeding was done in other areas. The same practice was followed the following year in other areas that helped minimise Shochum growth.
7. Mechanical weeding is also employed as they feel that line transplanting allows more tiller formation thereby increasing straw production besides the ease of harvesting and overall labour cost reduction.

Lango Geog

1. Intensive hand weeding is practised to control Shochum.
2. Shochum is disposed off properly – buried in the soil or left to dry in dry areas.
3. Farmers are cautious about irrigating their fields through water from Shochum infested fields into clean fields.

Tsento Geog

1. Shochum has been contrlled via intensive weeding (3-4 times in a season); no chemical control has been implemented till date.
2. Incorporation of weed (Shochum) flushes is practised here which according to the farmers is said to control the weed but needs more data to support this.

Shaba Geog

1. The farmers have continued intensive weeding for the last 5 years and they feel that it has brought positive impact in controlling Shochum.
2. The farmers here believe that the use of chemical will result to more weed growth and resurgence of other minor weeds.

Conclusion

As conceived, the study tour was very consequential, with farmers expressing their views on the real intensity of Shochum. In fact, most farmers were not aware of the yield loss as well as prolific nature of this weed till they were briefed and had interacted with the farmers of Paro. However, at the end of the farmer-to-farmer discussion all participants felt that this was an experience worth implementing in the course of rice production endeavours. All farmers felt the need to take some urgent measures learnt from Paro in their fields in the coming season. As suggested by experienced Paro farmers, participants expressed their interest to try in some locations (area wise in alternative year) and increase their efforts over a period of time covering the whole areas with time, besides being able to demonstrate to their neighbours. They felt the tour was timely and found that they could grasp the objectives clearly through frank and open discussions that they had with their fellow farmers of Paro Dzongkhag. They all have high hopes of following Paro's achievements and felt that they too could do so with technical backstopping from the dzongkhag extension services, research centre and other relevant institutions in due course of time.

Recommendations

1. In order to have the impact of the tour it is felt necessary to follow up on the following agenda:
2. Follow up of the tour with the selected farmers and emphasis on the lesson learned from this tour.
3. Conduct farmer-to-farmer training in relevant villages with the selected farmers as trainer.
4. Conduct intensive hand weeding programme with those selected farmers in next season on small location (area wise in alternative year).
5. Study tour back to Paro after five years to compare the changes of the past and then.

5.5.3 Fruit Fly Research

Citrus fruit drop is one of the major impediments to citrus production in Bhutan. Though substantial works on the fruit fly (*Bactrocera minax)* control have been attempted in the past the emergence of this insect in different agro ecological zones still remains doubtful. Until the exact emergence period of this insect pest is realized across different agro ecological zones the citrus production in Bhutan seems to remain stagnant. As such in an attempt to contain this insect pest NPPC in Semtokha and RNRRC, Bajo initiated a joint collaborative research with the primary objective of determining the emergence period of adult flies and efficacy of different protein baits. With TA inputs from ACIAR, Australia a trial was conducted in Tsirang for which a site was selected jointly by the Entomologist and researcher from RNRRC, Bajo in consultation with DAO (District Agriculture Officer), Tsirang.

Currently data for the year 2000 have been placed on record from which the following deductions can be made:
Peak catches of both males and females occurred in May (Figure 13). After the end of July the number of flies caught in lures decreased.

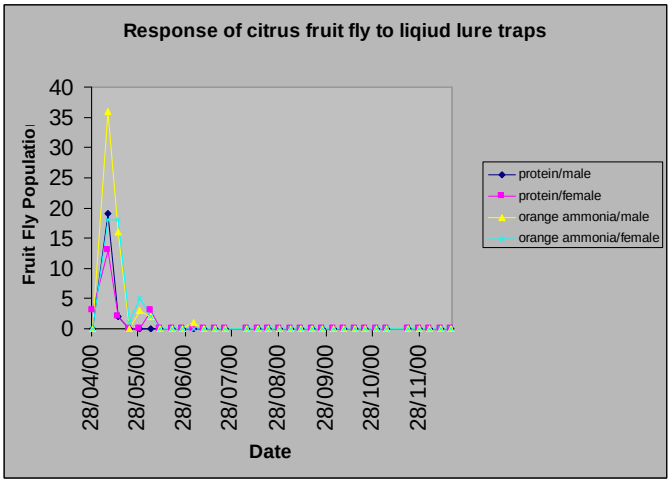


Figure 13:Citrus fruit fly caught in different liquid lure traps

The peak attraction to protein hydrolysate lures occurred at the time when the females were approaching sexual maturity. The response to protein lures then seemed to decline markedly once the females had matured their first batch of eggs. This indicates that protein bait sprays would be most effective against the adult population in the orchard when applied in early to mid-June.

The pheromone dry trap trial using methyl eugenol and cue lure was also carried out concurrently. The fruit flies caught in each traps were collected on weekly basis and sent to NPPC for dissection to determine the oviposition period. According to Dr. Brian Fletcher, Fruit fly consultant we do not know the peak and duration of oviposition in mandarin fruits but it would appear to be somewhere between late June and early September. He has prioritized bagging and subsequent exposure of fruit experiment to determine and quantify the oviposition period for the next season (2001).

Appendix 1: List of local rice germplasm rejuvenated and characterized in 1999.

Acc. No.	Variety	50% FLW (days)	Height (cm)
	Sung Sung	118	76
	Jung Bar	127	76
	Pang Bar	119	122
	Ash Chalu	127	112
	Jamkharpa	142	125
	Bepu Bara	-	
	Takulung Bara	142	132
	Bidhungpa	127	123
	Bomlingpa	127	119
	Asu	127	113
	Khardungpa	127	138
	Baypo	120	111
	Pang Bara	119	128
	Gasha Bara		
	Baypu Asu	119	111
	Zubara		
	Brayna	122	142
	Takulung Bara	142	132
	Yeshi Zangpo	117	140
	Ow-Map	127	143
	Shagi Toli	127	116
	Ow-Map	127	139
	Toli Map	142	122
	Zanam	127	144
	Tshelap	127	135
	Dungchem	113	93
	Guenja	127	115
	Tan Tsheri	127	135
	Bondey	142	135
	Bondey sap	127	161
	Chumja	142	146
	Dawa	142	142
	Wangdakum	127	158
	Macha	115	145
	Phulisu	127	119
	Jarey Map	119	110
	Beybukap	142	138
	Gyemza Map	142	163
	Nobza White	142	138
	Chumza	127	161
	Wolanam	119	159

	Dawa Wangkum	127	144
	Botoley	127	120
	Janam	127	147
	Wangkum	142	136
	Bondey	119	77
	Zaga Shochu	113	100
	Jarey Kap	127	112
	Botoli	127	111
	Pamja	127	141
	Geuija	115	
	Rinzi Dem	142	134
	Sangay Rinchen	107	86
	Tan Tshering	127	132
	Chumza	142	146
	Jaray	116	113
	Zongkha	127	75
	Apa Dodo	142	129
	Chumja	127	154
	Gyemja	127	110
	Janam	142	147
	Brena		
	Mebar		
	Mebra	107	122
	Mebra		
	Pure Mebra		
	Vrena		
	Rangshi Kharpa		
	Brana		
	Phongmepa		
	Pang Bara		
	Pangshi Karpa		
	Thongrangpu		
	Jamkharpa	127	143
	Asu	122	120
	Thongrangpa Salu	127	135
	Sharpa Bara		
	Pang Bara		
	Mongar Bara		
	Ijung		
	Mongarpa		
	Wangdi Karma		
	Nagakhaly		
	Kolomeya		
	Tingrey		
	Tsho Bara		
	Choto Mosino		
	L Kaap		

	L Maap	127	142
	Bumtel Nip		
	Maap		
	Zhakha	127	104
	Bra-Changloo		
	BR-153	142	88
	Wandey karma	142	128
	BR-153	142	91
	Wangdi Karma	142	141
	Wangdi karma	119	154
	Sambara	122	148
	Yangtsipa Bara	127	141
	Aasu	127	119
	Sung Bara	122	155
	Kanpara Bara	127	83
	Robtang Bara	127	133
	Dasa Bara	127	126
	Karma Lelepa	127	132
	Baismutay	142	82
	Aaizum	142	102
	Kamshing	142	132
	Unknow	127	116
	Korphupa	123	139
	Khangmala	123	143
	Pokchilu	123	156
	Weedi type	123	150
	Dangphu Bra	123	127
	Sharchokpa	123	138
	Pokchila	123	157
	Korphugpa	123	144
	Sharchopa	123	139
	Khangmala	123	144
	Pokulung	127	128
	Unknown	127	133
	Sharchokpa	123	135
	Korphupa	123	132
	Pokchila	123	154
	Khangbala	123	130
	Kamsing Kharti	127	127
	Sharchungpa	123	138
	Korphogpa	123	138
	Khangbala	123	118
	Pugchela	123	175
	Kamshing	127	127
	Shentila	127	126

Appendix 2: Details of the Potato Seed Quality assessment study

Location	Bajo
Planting date	28.2.2000
Weeding and interculture operations	20.3.2000 1ST IRRIGATION
Top dressing date	25.4.200
Plot size	2.4 m X 3 m with a spacing of RR 0.6m, PP 0.25m.
Harvesting date	9.6.2000

Geog Phobjikha, Village Damji Lakha

Sam. No	Farmer	Variety	Seed source	Year	Seed size L (cm)	b	Sprout type	Sprout length (cm)	Shrin-kage	Wounds
P1	P Farm	K Jyoti	DSC	3	4.3	3.5	no	no	no	No
P2	P.Lekha	Yusikaap	DSC	3	4.5	4.5	AD	1.0	no	no
P3	P farm	Desiree	BNPP	3	4.8	3.7	no	no	no	no
P4	Penjor	Maap	DSC	2	7.3	4.6	AD	4.0	no	no
P5	Dago	Maap`	Other farmers	15	6.5	4.2	AD	no	no	no
P6	Kinlay	Maap	Other farmers	15	5.5	4.3	no	no	no	no
P7	Gyem, Lam	Kaap	Own	10	6.6	4.8	AD	4.0	no	no
P8	Phurba	Maap	DSC	3	4.3	3.5	no	no	no	no
P9	Doley	Maap	Own	30	9.0	5.5	AD	3.5	no	no
P10	Naphela	Maap	DSC	10	7.3	4.6	AD	5.6	no	no
P11	Wangchok	Kaap	Own	5	4.8	4.5	AD	2.0	no	no
P12	Tshering geltshen	Maap	Own	9	5.1	3.0	no	no	no	no

Phobjikha									
Sam. No	Emerg. 50 DAP	Yield Small		Seed size		Large			
		Nos	Wt	Nos	Wt	Nos	Wt	Total (kg/plot)	Total (t/ha)
P1	21	57	1.4	65	3.1	19	2.5	7	19.44
P2	23	87	3.3	58	2.9	8	1.0	7.2	20.00
P3	24	26	0.6	52	2.4	21	2.3	5.3	14.72
P4	23	66	1.5	75	4.4	23	2.5	8.4	23.33
P5	22	106	2.0	78	4.2	12	1.0	7.2	20.00
P6	23	96	2.0	62	3.5	20	2.2	7.7	21.39
P7	24	80	1.4	68	4.9	28	3.0	9.3	25.83
P8	22	84	1.6	49	4.4	16	1.5	7.5	20.83
P9	24	68	1.6	75	4.0	30	3.2	8.8	24.44
P10	24	128	2.7	56	2.9	40	3.8	9.4	26.11
P11	24	66	2.1	56	2.9	16	1.5	6.5	18.06
P12	23	99	2.2	72	4.8	18	2.2	9.2	25.56

DSC									
D1	23	82	1.6	65	3.7	24	2.6	7.9	21.94
D2	24	99	2.0	72	3.3	12	1.5	6.8	18.89
D3	24	82	1.8	60	3.4	22	3.1	8.3	23.06

Geog: Sephu, Village Rukubji

Sam. No	Farmer	Variety	Seed source	Year	Seed size L (cm)	b	Sprout type	Sprout length (cm)	Shrin-kage	Wounds
S1	Tshering Dorji	Maap	BNPP	1996	6.8	3.6	no	no	no	1%
S2	Kuenzang	Maap	BNPP	1996	7	4.66	no	no	no	No
S3	Letho	Maap	Other	1995	7.2	4.5	no	no	no	No
S4	Phub Zam	Kaap	Own	1990	5.8	4.6	no	no	no	no
S5	Lam Dorji	Maap	DSC	1998	6.8	5.0	AD	0.7	no	no
S6	Namgay Dem	Maap	BNPP	1995	6.3	3.6	no	no	no	no

Sephu									
Sam. No	Emerg. 50 DAP	Yield Small		Seed size		Large			
		Nos	Wt	Nos	Wt	Nos	Wt	Total (kg/plot)	Total (t/ha)
S1	23	126	2.5	75	4.1	21	2.6	9.2	25.56
S2	23	94	1.8	64	3.6	18	1.4	6.8	18.89
S3	24	100	2.4	44	3.1	30	3.0	8.5	23.61
S4	22	72	1.9	54	3.0	20	2.3	7.2	20.00
S5	23	86	1.4	80	3.8	12	1.0	6.2	17.22
S6	22	120	2.7	73	3.6	12	1.1	7.4	20.56

Geog: Bjena, Village Khotokha

Sample No	Farmer	Variety	Seed source	Year	Seed size L (cm) b		Sprout type	Sprout length (cm)	Shrinkage	Wounds
K1	Wangchuk	K Jyoti	Other	9 yrs old	5.0	4.3	no	no	no	No
K2	Kinlay Wangdi	Maap	DSC	11 yrs old	7.3	4.5	no	No	no	no
K3	Ugen Zam	Maap	Other	1998	8.7	6.2	no	no	no	1%
K4	Chime Om	Maap	DSC	1996	5.8	4.8	no	No	no	no
K5	Karma	Maap`	BNPP	10 yrs old	7.3	4.2	No	no	no	no
K6	Khandu	Maap	BNPP	10 yrs old	6.7	4.7	no	no	no	1%
K7	Tetsu	Kaap	Other	8 yrs old	6.3	4.8	no	no	no	no

Khotokha									
Sample No	Emerg. 50 DAP	Yield Small Seed size Large							
		Nos	Wt					Total (kg/plot)	Total (t/ha)
K1	22	82	1.5	61	3.0	28	2.8	7.3	20.28
K2	24	156	2.4	68	2.2	36	3.5	8.1	22.50
K3	18	106	11.4	57	2.4	25	2.2	16	44.44
K4	24	120	1.9	70	3.3	22	2.1	7.3	20.28
K5	23	180	2.2	60	2.0	20	1.5	5.7	15.83
K6	24	147	2.3	86	3.4	24	1.9	7.6	21.11
K7	23	100	1.5	48	2.3	26	2.0	5.8	16.11

Geog Limbukha, Village Limbukha

Sample No	Farmer	Variety	Seed source	Year	Seed size L (cm)	b	Sprout type	Sprout length (cm)	Shrinkage	Wounds
L1	Namgay Dorji	Maap	Phobjikha	1997	6.3	4.0	Senile	2.5	Heavy	No
L2	Sangay	Maap	Limbukha	1996	5.2	3.8	Normal	3.5	Medium	No
L3	Kencho Tshering	Maap	Limbukha	1997	5.7	3.8	Normal	3.8	Medium	no
L4	Dema	Maap	Phobjikha	1998	3.8	2.8	Senile	5.0	Heavy	no
L5	Passa	Maap	Other farmer	1995	5.7	3.8	Normal	2.7	Medium	no
L6	Nam	Maap	Phobjikha	1997	5.6	3.5	Normal	2.8	Heavy	no
L7	Chime Rinzin	Maap	Local	1997	5.5	3.3	Senile	4.5	Heavy	no
L8	Passang Om	Maap	Phobjikha	1996	5.8	4.3	Senile	5.8	Medium	no
L9	Kinlay	Maap	market	1990	5.6	4.3	Senile	2.6	Medium	no
L10	Wangdi	Maap	Phobjikha	1998	6.6	4.6	Normal	3.3	Heavy	no

Limbukha									
Sample No	Emerg. / plot 50 DAP	Yield Small size		Seed size		Large			
		Nos	Wt					Total (kg/plot)	Total (t/ha)
L1	24	152	2.1	42	2.4	10	0.8	5.3	14.72
L2	24	100	1.9	60	3.1	19	1.6	6.6	18.33
L3	24	152	2.5	52	2.4	28	2.1	7	19.44
L4	23	140	2.5	68	3.3	23	2.3	8.1	22.50
L5	24	140	2.8	82	3.9	30	2.6	9.3	25.83
L6	24	135	2.3	63	2.8	31	2.9	8	22.22
L7	24	166	2.8	56	2.7	26	3.1	8.6	23.89
L8	24	200	2.6	60	2.6	26	1.95	7.15	19.86
L9	29	155	2.4	52	2.3	0	0	4.7	13.06
L10	23	161	2.2	68	2.5	19	1.4	6.1	16.94

Appendix 3: Summary of growing stock: Lingmutey Chu watershed.

Species	Cover %	Basal Area	Dia-range	Avg. Ht	TB Qty
ACEL	40	6	39-45	21	Good
ALB?	40	4	20-50	15-40	Medium
BEIG	80	1	16	10	Good
BENC	40	1	17-30	10-14	Fair
BETA	75	4	29-81	25-30	Good
BRL?	80	2	20-30	10-20	Good
Carpinus	60	2	39	25	Fair
CAT?	63	10	20-100	10-40	Medium
CELA	89	7	30-140	30-45	Medium
Chakpashing	85	2	20	32	Good
Chiblam	65	3	30-100	35-45	Medium
Chindey	67	3	30-45	30-40	Medium
CIN?	80	5	18-43	18-50	Good
CLVA	40	2	27	25	Medium
ELAI	60	6	62	35	Good
ELAV	70	3	28-48	30-35	Medium
EURC	75	4	10-50	6-18	Medium
EXBP	80	2	35	22	Poor
FCc	26	10	20-80	10-30	Good
Gayshing	85	2	131	37	Medium
Guli Tsher	85	4	40-103	20-30	Good
Gulishing	70	2	64	40	Poor
Hoenshing	55	10	30-70	20-25	Medium
Kafal	50	1	16	8	Poor
LYOO	43	3	10-45	6-15	Fair
MAAD	40	2	29	23	Fair
MICD	75	6	20-60	20-40	Good
Mictoctia	85	2	30	35	Good
MYRE	59	9	12-60	Oct-40	Medium
Ninguli	85	6	20-150	20-30	Good
PER?	70	2	48-80	20-35	Medium
Phunchey	40	17	36-74	18	Medium
PINR	30	12	15-60	15-30	Good
Pragoli	60	3	55-60	25-30	medium
PRUE	65	3	30-40	25-30	Good
Pumoloto	60	2	50	25	Fair
QUEL	77	9	20-120	Oct-50	Good
QUEM	60	31	140	35	Good
QUEN	55	6	10-70	10-35	Medium
QUER	53	6	20-100	Oct-35	Poor
RHO?	41	6	10-40	5-15	Poor
RHUH	45	2	35-40	30	Good
SCHW	50	2	15-30	20-40	Medium
Shingka	80	1	19-40	15-40	V.good
SYMP	66	2	13-36	10-30	Good
SYZU	43	3	15-60	Oct-30	Medium

Appendix 4: Literatures on Parthenium hysterophorus

(Source: PP2 November 1999 Produced by: Land Protection Agdex 647 The State of Queensland ISSN 1327-5402)

The weed

Parthenium weed is an annual herb with a deep tap root and an erect stem that becomes woody with age. As it matures, the plant develops many branches in its top half and may eventually reach a height of two metres. Leaves are pale green, deeply lobed and covered with fine soft hairs. Small creamy white flowers occur on the tips of the numerous stems. Each flower contains four to five black seeds that are wedge shaped, two millimetres long with two thin, white scales.

The problem

Parthenium weed is a vigorous species that colonizes weak pastures with sparse ground cover. It will readily colonize disturbed, bare areas along roadsides and heavily stocked areas around yards and watering points. Parthenium weed can also colonize brigalow, gidgee and softwood scrub soils. Its presence reduces the reliability of improved pasture establishment and reduces pasture production potential. In 1992, it was estimated that parthenium weed cost the beef industry $16.5 million per year, including reduced beef production and control costs. Parthenium weed costs cropping industries several million dollars per year also. Parthenium weed is also a health problem as contact with the plant or the pollen can cause serious allergic reactions such as dermatitis and hay fever.

Life cycle

Parthenium weed normally germinates in spring and early summer, produces flowers and seed throughout its life and dies around late Autumn. However, with suitable conditions (germinating rain, available moisture, mild soil and air temperatures), parthenium weed can grow and produce flowers at any time of the year. In summer, plants can flower and set seed within 4 weeks of germination particularly if stressed.

Where does it occur?

Parthenium weed is capable of growing in most soil types but becomes most dominant in alkaline, clay loam soils. Parthenium weed is a native of subtropical areas in South and North America and was initially recorded at Toogoolawah in 1955. A second introduction occurred north of Clermont in 1960. Unfortunately its early establishment was ignored. The plant is now well established in central Queensland and present in isolated infestations west to Longreach and in northern and southern Queensland. Infestations are also found in northern and central parts of New South Wales and it is capable of growing in most states of Australia.

Prevention and spread

Pastures maintained in good condition, with high levels of grass crown cover, will limit parthenium weed from colonising. Drought, and the subsequent reduced pasture cover, creates the ideal window of opportunity for parthenium weed colonisation when good conditions return. As with most weeds, prevention is

much cheaper and easier than cure. Parthenium seeds can spread via water, vehicles, machinery, stock, feral and native animals and in feed and seed. Drought conditions aid the spread of seed with increased movements of stock fodder and transports. Vehicles and implements passing through parthenium weed infested areas should be washed down with water. Washdown facilities are located in Alpha, Biloela, Charters Towers, Emerald, Gracemere, Injune, Monto, Moura, Rolleston, Springsure and Taroom. Particular care should be taken with earthmoving machinery and harvesting equipment. The wash down procedure should be confined to only one area, so that any plants that establish from dislodged seed can be destroyed before they set seed. Extreme caution should be taken when moving cattle from infested to clean areas. Avoid movement during wet periods as cattle readily transport seed in muddy soil. On arrival cattle should be held in yards or small paddocks until seed has dropped from their coats and tails prior to release into large paddocks. Infestations around yards can be easily spotted and controlled whereas infestations can develop unnoticed in large paddocks. Particular care should be taken when purchasing seed, hay and other fodder materials. Always keep a close watch on areas where hay has been fed out for the emergence of parthenium or other weeds. Property hygiene is important. Owners of clean properties should ensure that visitors from infested areas do not drive through their properties. If your property has parthenium weed on it, ensure that it is not spread beyond the boundary or further within the property.

Control
Control of parthenium weed infestations should revolve around pasture management, biological control and timely herbicide treatment.

Pasture management
Grazing management is the most useful method of controlling large-scale parthenium weed infestations. Maintain pastures in good condition with high levels of ground and grass crown cover. This may require rehabilitation of poor pastures, followed by a sound grazing maintenance program.

Sown pasture establishment
Poor establishment of sown pastures can allow parthenium weed colonization. Contact your local Department of Primary Industries Pasture Agronomist for species selection and sowing guidelines to suit your particular situation. Aerial seeding prior to scrub pulling is normally beneficial.

Overgrazing
High pressure caused by drought or high stock numbers, decreases the vigour and competitiveness of pastures and allows the entry and spread of parthenium weed. Maintenance of correct stock numbers is most important in controlling parthenium weed. For more information on stocking rates for your situation consult a Department of Primary Industries Pasture Agronomist.

Pasture spelling
In situations of serious infestation, pasture spelling is essential for rehabilitation. Total spelling is much more effective than simply reducing the stocking rate.

However, overgrazing of the remainder of the property must also be avoided. The most appropriate time for pasture spelling is the spring-summer growing period, with the first 6-8 weeks being particularly important. If the condition of perennial grasses (native or sown) is very low, spelling for the entire growing season may be required or introduced grasses may need to be resown. Herbicide treatment can hasten the rehabilitation process by removing a generation of parthenium seedlings and allowing grass seedlings to establish without competition. In the presence of parthenium weed, grass establishment is poor. Grazing during winter should not increase the parthenium weed risk. Most tropical grasses are dormant and can tolerate moderate grazing during this period. However parthenium weed may germinate and grow at this time.

Fencing
One of the main problems in controlling parthenium weed is the large paddock size and the variability of country within paddocks. The resulting uneven grazing pressures encourage parthenium weed to colonise the heavily grazed country. Ideally similar land types should be fenced as single units. Fencing can be used to great effect to break up large paddocks, allowing more flexible management such as pasture spelling or herbicide application, options not available previously.

Burning
Burning is generally not a management option for parthenium weed.

Herbicide control

Non-crop areas
Parthenium weed should be sprayed early before it can set seed. A close watch should be kept on treated areas for at least 2 years. Small and/or isolated infestations should be treated immediately. Herbicide control will involve a knockdown herbicide to kill plants that are present and a residual herbicide to control future geminations. Repeated spraying may be required even within the one growing season to prevent further seed production. Extensive infestations will require herbicide treatment in conjunction with pasture management. Timing of spraying is critical so that parthenium weed is removed when plants are small and before seeding has occurred. Grasses should be actively growing and seeding so that they can recolonise the infested area. Before using any herbicide always read the label carefully. All herbicides must be applied strictly in accordance with the directions on the label.

Cropping areas
Controlling parthenium weed in cropland requires selective herbicide use and/or crop rotations. For further information on parthenium weed control in crops consult your nearest Department of Primary Industries Extension Agronomist.

Biological control
So far, nine species of insect and a rust pathogen have been introduced to control parthenium weed. The moth *Epiblema strenuana* (introduced from Mexico) is established in all parthenium weed areas. The moth's larvae feed inside the stem, forming galls which stunt the plant's growth, reduce competitiveness and seed production. *Listronotus setosipennis* (stem boring weevil from Argentina) is having limited success in reducing the vigour of

parthenium weed infestations. *Zygogramma bicolorata* (defoliating beetle from Mexico) is highly effective where present. It emerges in late spring and is active until autumn. *Smicronyx lutulentus* (Mexico) lays eggs in the flower buds where the larvae feed on the seed heads. *Conotrachelus albocinereus* (stem galling weevil from Argentina) produces small galls and is still becoming established in Queensland. *Bucculatrix parthenica* (leaf mining moth from Mexico) larvae feed on leaves, leaving clear windows in the leaf. *Puccinia abrupta* (winter rust from Mexico) requires a night temperature of less than 16C and moderate leaf moisture. *Carmenta ithacae* (stem boring moth from Mexico) has recently been released from quarantine and has yet to become established. The combined effects of biological control agents reduced the density and vigour of parthenium weed and increased grass production.

Manual control
Hand pulling of small areas is not recommended. Firstly there is a health hazard from allergic reactions and secondly there is a danger that mature seeds will drop off and increase the area of infestation.
Further information
Land Protection Officers, Department of Natural Resources, 1800 803 788 (local call) or 07 32277111 (Brisbane).

Local Government Stock Routes Supervisors and Weeds Officers.

Parthenium Action Group 07 4984 3266 (Rolleston) or 07 4983 4743 (Clermont).

Information on the biocontrol agents can be obtained on www.ctpm.uq.edu.au. Brochure partly funded by Rural Lands Protection Fund.

(Source: http://www.ctpm.uq.edu.au/parthenium/abstracts.html)

Parthenium

Scientific name:	*Parthenium hysterophorus* L.
Sub tribe:	Ambrosiinae
Tribe:	Heliantheae
Family:	Asteraceae
Common name:	Parthenium weed, parthenium, White top, False Ragweed

Biology
A short-lived ephemeral herb, reaching 2m tall in good soils, usually 50 to 150cm, germinating after rain at any season, flowering in 6 to 8 weeks, and senescing with drought or frost. Reproduces by small seeds lasting up to 20 years in soil, induced dormancy on burial (Navie et. al. In Press).

Native Range
P. hysterophorus is native to the countries bordering the Gulf of Mexico, and has spread throughout the southern U.S.A., Mexico, the Caribbean and Brazil (Navie et al 1996). A slightly different race of *P.hysterophorus*, with yellowish flowers, is

native to central South America (Argentina, Bolivia, Chile, Paraguay, Peru and Uruguay). The probable geographic centre of origin is the countries around the Gulf of Mexico.

Parthenium Taxonomic Affinities

Within the genus *Parthenium*, only one species, *Parthenium argentatum* Gray (guayule), is of potential economic value. Guayule has frequently been suggested as a potential source of natural rubber, but has never been commercially exploited. *P. argentatum* is chemically and morphologically very different to *P. hysterophorus* (Stuessy 1977) and their insect and disease complexes are also different (McClay et al. 1995).

Parthenium is in the sub-tribe Ambrosiinae of the tribe Heliantheae and is closely related to the genera *Xanthium, Ambrosia, Iva, Hymenoclea, Dicoria, Parthenice* and *Euphrosyne*. These are all weedy genera occurring in the Americas and none contain any species of economic value. Within Australia, *Ambrosia* and *Xanthium* are represented by ten species of introduced noxious weeds. *Iva* is represented in Australia by two species, both noxious weeds with a limited distribution in Victoria and South Australia (Parsons & Cuthbertson 1992).

Within the tribe Heliantheae, sunflower (*Helianthus annuus* L.) and Jerusalem artichoke (*Helianthus tuberosus* L.) are the only crop plants of economic importance in Australia. *Guizotia abyssinica* (Niger seed) is not grown in Australia. Several introduced ornamentals are of economic importance, among them *Zinnia, Gaillardia, Coreopsis, Cosmos, Dahlia*. There are Australian natives in several genera including *Wedelia, Glossogyne* and *Spilanthes*: in general, however, the Heliantheae are poorly represented in the endemic Australian flora.

Considering the Asteraceae as a whole, there are numerous Australian native species, particularly in the Astereae, and ornamental plants in several genera, and four crop plants of varying importance: *Carthamus tinctorius* (safflower), *Chrysanthemum cinerariaefolium* (pyrethrum), *Cichorium intybus* (chicory) and *Lactuca sativa* (lettuce).

Parthenium Pest Status

Parthenium weed is an invasive annual of open land and pastures. It is unpalatable to stock, and on suitable soils in the summer rainfall tropics and sub-tropics, will quickly dominate both native and planted pastures particularly where these are overgrazed. Once dominant, parthenium weed continues to persist as pure stands unless managed. Plants are capable of flowering when one month old and will remain in flower for 6-8 months when conditions are suitable.

Plants produce large numbers of seeds which are transported by water, on vehicles and equipment, or in soil or mud adhering to vehicles, equipment and animals. Hence its spread is associated with roadways, stockyards, or movement of animals generally. New outbreaks in clean areas have been linked with movement of earthmoving and harvesting machinery, and transport of stock, fodder and grain from parthenium-infested areas.

Seeds will remain viable on the soil surface for up to two years, or longer if there is no rain to stimulate germination. Buried seed may become dormant and remain viable for much longer periods (Navie *et al.* in press).

In central Queensland, parthenium weed quickly invades disturbed soils such as overgrazed pastures and newly cleared or eroded lands, where it remains dominant unless the appropriate management techniques are applied.

Management requires de-stocking to allow grass growth, followed by the reduction of stocking rates by about 40% to prevent re-invasion.
Ingestion of the plant produces unacceptable taints in mutton (Tudor *et al*. 1982). The plant causes acute allergic eczematous dermatitis in humans, which under continued exposure becomes chronic. Highly sensitised individuals are forced to avoid contact with the plant entirely. In some situations, landholders and other workers are forced to move from the district or cease their normal activities. Up to 10% of people living in parthenium weed areas in India suffer from allergic rhinitis and sinusitis (hayfever) (Tower and Subba Rao 1992).

Parthenium Biological Control Agents

The fight against Parthenium using biological control methods commenced in 1977. Presently seven insects and one pathogen (rust) have been released to combat parthenium in Queensland. The 6 biological control agents described are present and seasonally abundant in parthenium areas of Queensland. Their development is optimal at summer temperatures between 25 and 35¡C and slows down in cooler weather except for the parthenium rust. Seasonal conditions and the need for green plants play a major role in the effectiveness and abundance of biological control agents. This is highlighted during long dry periods where insect populations are reduced and need time to recover.
Biological control agents should be used as one tool in a combined management strategy which also incorporates herbicide and mechanical control.

Parthenium - Other Control Methods
Once parthenium weed is established in pastures, control requires maintenance of good grass growth to maximise competition against the plant. This can only be achieved by initial destocking followed by reduced stocking rates to maintain grass competition (Holman and Dale, 1981; Anon. 1997).
While individual parthenium weed plants are easily killed with herbicides, rapid regeneration from seed soon follows. The only successful way to control the plant with herbicides is to use residual pre-emergent compounds and several retreatments are necessary to prevent further seed production (Anon. 1997). Eight species of insect and a rust disease have been introduced since 1979 (Navie et al 1996). Six species are established; a stem-galling moth *Epiblema strenuana* (Lep.: Tortricidae), a leaf-mining moth *Bucculatrix parthenica* (Lep.: Bucculatricidae), a stem-feeding weevil *Listronotus setosipennis* (Col.: Curculionidae), a stem-galling weevil *Conotrachelus* sp. (Col.: Curculionidae), a seed-feeding weevil *Smicronyx lutulentus* (Col.: Curculionidae), and a leaf-feeding beetle *Zygogramma bicolorata* (Col.: Chrysomelidae), and the rust *Puccinia abrupta* var. *partheniicola.* Their combined impact is currently being evaluated in a 3-year project (Dhileepan *et al*. 1996). Preliminary results indicate that the impact is significant in wetter years and zones, reducing the weed's competitiveness and assisting management in grazing properties. Control is however far from adequate and parthenium weed is still one of the major weeds of the brigalow soils of central and northern Queensland (V. Pope, unpub. data, 1990).

Appendix 4: List of Visitors to the Centre from July 1999 to June 2000

Date	Visitor Name	Purpose
7/9/99	Dr. Walter Rodder Mr. Sonam Norbu Mr. T.R Gurung Mr. V. Moktan Mr. T.B Katwal Mr. Kencho Dr. Christopher Floyd Mr. Dawa Penjore Dasho Sherab Gyeltshen	Field crop coordination meeting
11/13/1999	Acting Director All Dzongkhags RNR Sector Head Planning Officers	RNR 5th Review and planning workshop
7/11/1999	UNDP Associate Administrator	Visit for IHDP Programmer
9/11/1999	Ms. Ditdit R. Pelegrina	To discuss BUCAP proposal
6/10/1999	Mr. Doming F Tabal (Associate Scientist, IRRI)	To impart training on water management
20/11/1999	Mr. Prmod Pradhan	GIS Training
22/11/1999	Dr. Ian Baily Dr. Rupert Baumler	Soil Spray Project
28/11/1999	Dr. John Graham Dr. Mercedula A. Sombilla Mr. Harold John Nesbitt Mr. Domingo F. Tabbal Mr. Julian A. Lapitan	Review and Plannig of project activites
4/12/99	Mr. Ken Lee (Lotus foods U.S.A)	To discuss on red rice/ varieties being exported to us from Paro.
13/12/1999	Prof. Tae Soon Kwak (Sangji University, S. Korea.) Mr. Young-Wang Na (Genetic Res. Division RDA, S. Korea)	To discuss on exchange of technical info and crop germplasm
6/1/2000	Graduates (9) Nos.	Familiarisation Tour
2-4/3/2000	Dr. Hans Schreiber Dr. Liz Fajber Elizabeth	Preparation of Project activities related to Community based Natural Resources Management (CBNRM in the Lingmuteychhu water shed.
20/4/2000	Dr. Kasuho Makino	Familiarisation Tour

Date	Visitor Name	Purpose
12/4/2000	Dr. Vitoon Viriyasakultorn Kasetsart University P.O Box No. 111 Bangkok 10903 Thailand	As a facilitator for conflict Resolution workshop.
1/5/2000	Aum Chimme	Evaluation/monitoring/ Survey of kitchen gardening physically/ data collection and role of women in rural areas.
4/5/2000	Swiss Ambassador with other dignitaries	Visits to farm and watershed project.
6/5/2000	Dr. Dror Hadar	Plant protection expert
17/5/2000	Suresh Raj Challse Saleem .A. Sial	International center for integrated mountain Development
23/5/2000	Progressive farmer of Chukha Dzongkhag (22 Nos)	Study tour to the Center
17/6/2000	Nirmal Kumar Gaucham (District Development Committee) BiJaya Mom Sherchan (Mechanical Engineer) and Kishore Sherchamd (Senior Scientist, Nepal. Agri. Research Council)	Visit of Official from mustang DDC Nepal

Appendix 5: Training Attended by RNRRC Staff

Sl No	Name	Place	Period	Remarks
1.	Pema Dorji Sangay Dorji	India (Nagpur)	November 1999	International Symposium on Citriculture
2.	Karma Nidup	Taiwan	June-July 1999	IPM in eggplant fruit and shoot borer training
3.	Yuden Dorji	China	10 Oct-10 Nov 1999	Seminar in vegetable cultivation technology
4.	Jigme Norbu	Thailand (Chaingmai)	1999	Workshop
5.	Thinley Jamtsho	Philippines	March-May 2000	On the job training in water management
6.	Kezang Jamtsho	Netherland	Jan-March 2000	Training on water management
7.	Sangay Duba	Thailand	Feb 2000	Training on conflict Resolution
8.	M. Ghimirey & G.B Chettri	Philippines	March 28-April 11, 2000	International Rice Research Conference
9.	Dawa Zangpo	Philippines	March-April 2000	Training in Library Management
10.	Neelam Pradhan	Korea	29 June-23 August 2000	Training on Rice production technology
11.	Sonam Norbu	Malaysia	June 2000	Conference on PGR

Appendix 6: Financial report for 1 July 1999 to 30 June 2000

Object Classification	Amount in Nu
Personal emoluments	4105866.72
Other Personal Emoluments	683431.45
Travel	885679.50
Utilities – Telephone	166612.50
Utilities – Cable, tlx, fax,WT	48728.00
Utilities – Electricity	30606.83
S&M (Office Supplies)	146804.24
S&M (Fertilizers)	48567.00
S&M (Seeds & Seedlings)	1577.00
S&M (Uniform, Ext.Kits)	165651.00
S&M (Textbooks and journals)	10422.76
S&M (Other supplies & consumables)	22147.50
MOP (Building)	47519.84
MOP (Vehicle)	494210.84
MOP (Equipments)	136788.30
Opt. Exp. (Transportation)	7500.00
Contribution – PF	293538.00
Expenditure on structure – building	15123.20
TOTAL	**7310774.68**