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JOURNAL
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MINISTRY OF AGRICULTURE
THIMPHU, BHUTAN

Livestock

Fodder quality of *Ficus auriculata* in Bhutanese Environments

Kelzang Wangchuk[1], Karma Dorji[2],Ugyen Lhendup[3] and Tsering Gyeltsen[4]

ABSTRACT

Ficus auriculata, *a species of fig tree is widely used to augment winter fodder shortage in subtropical environments. Very limited studies were carried out to establish its nutritional qualities in Bhutanese environments. A study was conducted in 2004 with the objectives to quantify nutritional qualities and evaluate the effect of elevation and rainfall. 15 random samples were collected from 15 different sites under subtropical environment. Samples were collected from homogeneous trees in winter. Representative samples were analyzed for crude protein, acid detergent fiber, neutral detergent fiber, and dry matter digestibility.*

The nutritional properties were diverse and varied between sites. The nutritional quality was superior for trees at higher elevations and vice versa for the trees at lower elevations. It is concluded that there is diverse nutritional quality amongst populations of Ficus auriculata along environmental gradient.

KEYWORDS:

Ficus auriculata, nutritional quality, CP, NDF, ADF, elevation, rainfall.

INTRODUCTION

Tree fodders are an important fodder resource in the traditional farming system across the foothills of the Himalayas (Roder *et al.* 2003). In subsistence livestock farming largely prevalent in Bhutan,

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the use of tree fodder is strongly favored by small land holdings, low input production system, and extreme topography (Roder *et al.* 2001). The advantages of growing fodder trees are described by Roder *et al.* (2003).

Amongst fodder trees, Roxburgh's or the elephant ear fig (*Ficus auriculata*) a species of fig tree is the most widely used species in subtropical environments. *Ficus auriculata* is one of about 800 species of figs. In Bhutan, this tree is found in areas within the elevation range of 400 to 2000m asl (Grierson and Long 1983). Due to its wide range of adaptation, strong farmers' preference and good productivity, it is emerging as the most important fodder tree species in subtropical regions (Roder *et al.* 2003). Its fodder quality is superior to paddy straw, the main winter feeding in the rice growing regions of Himalayas (Roder *et al.* 2003).

The only published evidence available on nutritional quality of *Ficus auriculata* in Bhutanese environments is provided by Tamang (1988). Tamang (1988) conducted an analytical work on *Ficus auriculata* samples collected from western, central and eastern region in mid summer and early winter. However, his analysis does not encompass the influence of environmental factors on nutritional qualities. Therefore, the knowledge on the nutritional quality of this tree species along environmental gradient in Bhutanese environment is lacking.

This paper examines the nutritional quality of *Ficus auriculata* samples collected from 15 locations under 5 *Districts* representing subtropical Bhutanese environments. The objectives are to quantify the range of nutritional qualities of *Ficus auriculata* across Bhutanese environments and evaluate the effect of elevation and rainfall on its nutritional quality.

MATERIALS AND METHODS

Description of sampling sites and sample collection

The samples of *Ficus auriculata* were collected from 15 randomly selected locations in 5 *Districts* that represented the major subtropical climatic zone (Table 1). The sampling sites were within the elevation

range of 500 to 1950m receiving an average annual rainfall ranging from 200 to 4500mm. The samples were collected from the farmers' fields as well as from the forest. Samples were collected in winter because *Ficus auriculata* is an important source to augment fodder shortage in that particular season.

Table 1: Description of sample collection sites

Tree No.	GPS	Village/Geog	Rainfall	Altitude	Sample source	
					Forest	Farm
Trongsa						
1	N27.42566, E090.61860	Chamge/ Dragteng	1000-1500mm	1950m	-	✓
2	N27.35561, E090.56665	Bayling/ Langthel	1000-1500mm	1196m	-	✓
Zhemgang						
3	N27.22364, E090.64478	Pam/ Trong	1500-2000mm	1294m	-	✓
4	N27.10024, E090.75125	Zurphey/ Trong	1500-2000mm	540m	✓	-
5	N27.12531, E090.65622	Rani camp/Trong	1500-2000mm	1700m	✓	-
6	N27.12531, E090.65622	Rani camp/ Trong	1500-2000mm	1540m	✓	-
Chukha						
7	N27.04900, E089.56592	Wangkha/G abtsho	1500-2000mm	1700m		✓
8	N27.04761, E089.57603	Wangkha/G abtsho	1500-2000mm	1593m		✓
9	N26.92229, E089.54744	Rivana/Bongo	1500-2000mm	1548m		✓
10	N26.89190, 089.45303	Kamji/Galing	1500-2000mm	1463m		✓
11	N26.86142, 089.41612	Ramtey/P/ling	4000-4500mm	750m		✓

Lhuenste						
12	N27.67585, E091.25453	Baptong/Khoma	500-600mm	1620 m	✓	-
Mongar						
13	N27.26140, E091.26149	Kilikhar	700-800mm	1886 m		✓
14	N27.27538, E091.23732	Mongar	700-800mm	1640 m		
15	N27.27148, E091.20131	Mongar	700-800mm	1196 m		

Tree selection, sampling and sample size

In order to maintain homogeneity amongst trees, trees with similar characteristics were selected. The selected trees were 15 to 17 years of age with uniform height, disease and pest free and were not subjected to lopping over the last one year.

The leaves of different ages were randomly collected from each tree and mixed thoroughly. The final sample representing the tree was collected for chemical analysis. 15 representative samples were collected from 15 different sites in winter. Samples collected were cut into 2 to 4 cm length for uniform drying. The cut samples were oven dried for 24 hours at the temperature of 60^{o}C. The dried samples were later ground and subjected to nutrient analysis.

Laboratory analysis for nutrient content

A total of 60 finely ground samples from 15 trees were subjected to analysis for determining nitrogen (N %), Acid Detergent Fiber (ADF), Neutral Detergent Fiber (NDF), and Dry Matter Digestibility (DMD %).

a. Nitrogen

Content of Nitrogen (N%) was determined by the Kjeldhal method (AOAC 1990). The crude protein (CP %) was calculated as N%*6.25.

b. Acid detergent and neutral detergent fibers (ADF and NDF)
Contents of Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) of leaves were determined by the method of Van Soest *et al.* (1991).

c. Dry matter digestibility (DMD %)
The In Vitro DM Digestibility (IVDMD %) was determined following the procedures described by McLeod and Minson (1982).

Statistical analysis
The entire dataset was analyzed using statistical software Minitab version 14. One-way analysis of variance (ANOVA) was carried out to compare the chemical composition and dry matter digestibility between sites. Significant difference between individual means was identified using least significant difference (LSD) of means. Mean differences were considered significant at $P<0.05$. Standard errors of means were calculated using Microsoft Excel program.

Regression analysis was performed to evaluate whether elevation and rainfall are the predictors of nutritional properties of *Ficus auriculata*. The nutritional values of this study were compared with the published information on nutritional qualities of *Ficus auriculata*.

RESULTS AND DISCUSSION

Results

Nutritional qualities between sites

The nutritional parameters are reported in terms of % of total dry matter of sample. Dry matter digestibility was not significantly different between sites, however, significant differences were observed for ADF, NDF and CP between sites (Table 2). The ADF and NDF content was lowest for the sample collected from Pam under Trong geog in Zhemgang and the sample collected from Phuentsoling had the highest ADF and NDF content. Accordingly, the CP content was highest for the sample from Pam and lowest for the sample from Phuentsoling.

Table 2: Nutritonal qualities of *Ficus auriculata* between different sites.

Site	DMD %	ADF%	NDF%	CP %
Bongo	40.54 ± 0.17	31.75 ± 1.83	51.00 ± 0.07	6.23 ± 1.30
Dragteng	48.99 ± 397	36.00 ± 0.38	39.19 ± 2.15	10.39 ± 1.57
Gabtso	47.16 ± 2.68	36.69 ± 0.42	43.53 ± 0.49	8.99 ± 1.49
Gabtso	47.16 ± 4.59	36.69 ± 0.44	43.53 ± 0.73	8.99 ± 1.49
Galing	43.33 ± 1.34	44.35 ± 1.03	49.23 ± 0.01	6.89 ± 1.33
Khoma	43.85 ± 2.51	36.95 ± 0.77	47.79 ± 3.51	7.40 ± 1.36
Langthel	45.81 ± 2.02	36.42 ± 0.66	43.97 ± 0.72	6.70 ± 1.32
Kilikhar	47.59 ± 0.43	37.49 ± 0.84	41.00 ± 0.34	7.21 ± 1.43
Mongar	53.26 ± 3.99	37.41± 0.12	44.17 ± 0.13	8.05 ± 1.39
Mongar	46.03 ± 0.26	36.58 ± 0.29	48.87± 0.31	8.53 ± 1.37
Phuentsoling	42.08 ± 2.76	46.17± 0.15	52.89 ± 0.49	5.36 ± 0.95
Pam	45.49 ± 1.72	28.46± 0.44	33.44 ± 0.90	13.2 ± 1.33
Zurphay	45.91± 1.91	39.65± 2.78	46.74 ± 1.19	6.11 ± 1.03
Rani camp	49.49 ± 3.93	43.79 ± 1.29	50.87± 1.06	6.90 ± 1.13
Rani camp	46.99 ± 0.27	30.84 ± 0.36	42.62 ± 1.67	6.98 ± 1.13
P value	ns	*P*<0.001	*P*<0.001	*P*<0.001
LSD[1]	-	0.84	1.01	2.38

± Standard Error [1]Least Significant Difference of Means ns- Non Significant

Effect of elevation and rainfall on nutritional qualities of *Ficus auriculata*

Elevation and rainfall had no effect on dry matter digestibility of *Ficus auriculata* (Table 3). However, a significant positive correlation was observed between NDF and rainfall. Although, there was significant (P<0.05) positive correlation between ADF and the amount of annual rainfall, a significant negative correlation was found between ADF and elevation (Table 2). Correlation between CP and elevation was positive and highly significant (P<0.01).

Table 3: Effect of elevation and rainfall on nutritional quality of *Ficus auriculata*. Values in each cell represent the correlation coefficient of regression analysis

Quality parameter	Elevation	Rainfall
DMD %	0.26	0.30
NDF %	0.25	0.39*
ADF %	-0.31*	0.33*
CP %	0.62**	2.10

*$P<0.05$ **$P<0.01$

Nutritional quality compared with other published information

The nutritional quality found in this study is comparable with the figures of Tamang (1990) (Table 4). However, the figures of this study are slightly lower than those reported by other authors. The dry matter digestibility recorded in this study ranged from 40.54% to 53.26%.

Table 4: Comparison of nutritional qualities with published information on *Ficus auriculata*

DMD%	ADF%	NDF%	CP %	Author
40.54 – 53.26	33.44 – 52.89	28.46 – 46.17	5.36 – 13.2	Wangchuk *et al.*(this paper)
-	45.0 - 45.3	49.3 - 50.0	9.5 -10.0	Tamang (1988)
-	36.1	46.2	13.5	Pearson (1990)
	40.4 – 40.6	57.0 – 58.4	14.1 – 15.1	Thorne *et al.* (1999)
-	-	- - 14.8	12.9	Shrestha and Tiwari (1991)
-	-	-	12.0 – 13.0	Amatya (1990)
-	-	-	13.2	Mahato and Subba (1988)
-	-	-	17.0	Panday (1982)

Discussion

The results of this study represent the nutritional qualities of *Ficus auriculata* trees within the age of 15 to 17 years in winter and the locations within elevations of 540 to 1950m asl.

There is huge variation in nutritional quality of *Ficus auriculata* between different sites. Rajhan (1977) studied the variation in nutritive value of tree leaves and concluded that nutritive value of tree leaves vary with months and season. Thus, a huge variation in nutritive quality between sites can be attributed to the variation in climatic and soil conditions found at different elevations. This was expected because there are different vegetation zones with different climatic conditions within the elevation range of 200 to 2000m asl. These attributes of *Ficus auriculata* support the finding of Thorne *et al.* (1999) who indicated that *Ficus auriculata* populations may have considerable range of nutritional parameters such as CP, NDF and ADF offering scope for improvement through selection.

The study results showed that elevation and rainfall are good predictors of nutritional quality of *ficus auriculata*. At higher elevations, leaves have lower fiber content and higher CP content suggesting that the nutritive quality of this tree resource is superior at higher elevation. The inferior nutritional quality at lower elevations is indicated by higher fiber and low CP content of the leaves.

There is wide range of nutritive values of *Ficus auriculata* reported in this study while the nutritive values in published information of other authors were within a small range. The wide range of nutritive values in this study is attributable to large variations in nutritional qualities among samples from different sites falling under different agro-ecological zones.

CONCLUSIONS

Ficus auriculata is the most important fodder tree within elevation of 200 to 2000m asl. The nutritive values of *Ficus auriculata* vary with elevations and the amount of annual rainfall and the nutritional quality in terms of fiber and CP content is superior at higher elevations. However, this study has not covered soil and management factors

which are also the major determinants of nutritional quality. Since, the farmers' management practices and soil properties vary with elevations and locations, studies in immediate future need to quantify the effect of these factors on nutritional quality across regions. Accordingly, the future research should focus on optimizing fodder quality of this tree resource via development of location specific management strategies.

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Comparative Study of Broiler Feeds in Bhutan

Karma Nidup[1] and Pema Wangchuk[2]

ABSTRACT

The trial to asses the quality of two broiler feed types: i) Feed manufactured in Bhutan by Karma Feed Group (KFG) and ii) Feed imported from India manufactured by Samrat Feed Group (SFG), was conducted by determining their nutrient content, growth rates of broiler birds, and feed efficiency. To conduct this experiment, day old chicks (Vencobb strain) were divided into two groups, KFG 97 birds and SFG 99 birds, reared in the two separate pens at the College of Natural Resources poultry farm for 42 days. The live-weight gain, dressing %, and feed efficiency were better in SFG as compared to KFG. The feed conversion ratio for SFG and KFG broiler birds was 2.05 and 2.65 respectively. The two-sample t-test suggests that there is a significant difference ($P<0.05$) between live-weight of SFG and KFG birds. Similarly, the carcass weight was significantly ($P<0.05$) higher in SFG birds. This suggests that imported feed is of higher quality than in-country feed. This is due to high CP content, good feeding value, and better overall quality of ex-country feed when compared to in-country feed.

KEYWORDS:

Broiler birds, Samrat feed, Karma feed, nutrient content, growth rate, feed efficiency, Bhutan

INTRODUCTION

Poultry farming is an integral part of the Bhutanese farming system. The poultry development programme in Bhutan started in 1961 together with the first five-year development plans (Nidup, 2003: Nidup, 2005). Poultry farming is seen as business in many parts of the world but it was never seriously taken as an enterprise in Bhutan for

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very long time. It has always been family and village chicken farming rather than at commercial scale. Besides the state owned central and regional poultry farms, there are only couples of commercial poultry farms in Bhutan. The demand for eggs and chicken meat in Bhutan is enormous and it is on rise. The existing farms including the state owned central farms cannot meet these demand. Because of these, Bhutan imports huge amount of meat and eggs from neighboring states of India.

The Ministry of Agriculture (MoA) has been encouraging to establish commercial poultry farms particularly broiler farmers in the potential areas of Southern Bhutan where influence of religion does not restrict rearing of broiler chickens. The establishments of number of "small-scale" broiler farms (200-500 birds) in Tsirang district and by farmers in Samtse district during 2004 to mid 2006 are some encouraging activities initiated by the Department of Livestock, MoA, to promote broiler meat production in Bhutan. However, one of the bottlenecks in this important initiative has been lack of good broiler feed sources. The only national feed mill in the country is located at Phuntsholing and the broiler feed from this company has not been popular. Successful private farms such as Wangchutaba broiler farm in Thimphu district and Gurung broiler farm in Gelephu district have been importing feeds from India. It is not clear why the feed produced within the country is considered inferior or to what extent imported feed is superior. Like in many countries (Acamovic, 2002), it has also not been possible to get the details of the basis of nutrient standards feed companies have been using because of commercial confidentiality. For all these reasons, the main purpose of this experiment was:

- Assess nutrient content of broiler feeds produced in Bhutan (KFG) and imported from India (SFG)
- Determine growth rate of broiler birds
- Assess the efficiency of two categories of broiler feeds

MATERIALS AND METHODS

Experimental Area and Treatment

The experiment was conducted at the poultry farm of the College of Natural Resources (CNR) for duration 42 days. One hundred ninety six day old chicks (DOC) of terminal *Vencobb* strain were divided into two groups and reared in two separate pens. The experimental unit consisted of 97 birds for KFG and 99 birds for SFG, respectively. Both groups of chicks were fed *ad libitum* to ensure maximum growth rate. Initial weight and weighing at different intervals were taken using electrical weighing balance (Mettler – Toledo, type PJ 300, 5 kg capacity, made in Switzerland).

Housing Preparation and Stocking Density

Prior to the arrival of DOC, two brooding pens were washed and cleaned thoroughly with water and phenol. Brooding pens were air dried for two days after which sawdust was spread over the floor uniformly. A day before arrival of DOC, floor laid with sawdust were covered with old newspapers and the brooder boxes were placed in each brooding pen. The 100-watt electric bulbs (30 cm away from the floor) were placed in brooding boxes. To confine the chicks around the source of heat and to prevent draught, a brooder guard or chick guards were erected around the brooder using plywood. The electricity was put on for 48 hours so as to raise temperature of the floor of each brooding pen**.** All possible efforts were made to keep litter as dry as possible throughout the experiment. The litter which was 3-5 inches thick was stirred once in a week.

The floor spacing was measured with measuring tape (Fibreglass tape 30m Marker Fibrex). The stocking density, which is a measure of the number of birds placed in broiler house, was 2.98 sq ft per bird for KFG and 3.07 sq ft per bird for SFG. According to parkhurst and Mountney (1988), the space requirement per broiler bird is 0.7 sq ft but many studies showed that provision of larger floor spacing increases weight per bird and improves feed conversion ratio (Bilgili & Hess, 1995; Johari & Hussain, 1996). There is little or negligible difference in

stocking density (0.09 sq ft/bird) between two groups of birds. According to Dawkins *et al.* (2004), good housing conditions such as good air quality and ventilation, and litter quality, are more important to good physical health and minimization of mortality than stocking density itself. Both groups had good housing conditions including ideal stocking density to ensure the welfare of birds.

Feed Analysis and Aflatoxin Determination

Feeds were analyzed at Soil and Plant Analytical Laboratory (SPAL), Semtokha. The samples were divided into two parts, one for moisture content determination and other for analyzing nutrient content of feeds. The difference between initial and final weight of samples after having dried in the hot oven for 24 hours provided moisture content. The other part was used for determining nutrient content using Near Infra Red system (SFOSS NIR System Model 5000-M SL no S/N7362).

The feeds were also examined at the National Centre for Animal Health (NCAH) laboratory, Serbithang, Thimphu, determine the presence of aflatoxin, which is a metabolite of the fungus *Aspergillus flavus*.

Feeding and Watering Regime

The birds in both categories of feed were fed *ad libitum* and clean water was made available throughout 24 hours. Cheeke (1999) has suggested feed starter diet for three weeks. However, in this study, starter diet was fed for 24 days after which they were provided with mixture of starter and finisher in a ratio of 75% to 25% on 25th day, 50% to 50% on 26th Day, 25% to 75% on 27th Day, and 100% finisher by 28th Day. The idea behind this approach was to minimize stress in growing chicks due to change in feed and acclimatize them to finisher feed. Similar system of feeding regime is followed in Wangchuktaba broiler farm. The feeders used were combination of trough type aluminum line feeders and round hanging type feeders. The equipments used for watering was plastic circular waterers and locally made earthen pot fountain drinkers. Care was taken to minimize the wastage of feeds.

Slaughtering and Dressing

Slaughtering and dressing is the final step in the production of broiler chickens. Scientific literature recommends that feed is withdrawn from poultry prior to slaughter (Bilgili, 2002). Pre-slaughter fasting period not only minimize wastage of undigested feed that may be present in the gastrointestinal tract of broiler (Smidt *et al.,* 1964) but also reduce likelihood of ingesta and/or faecal contamination of the carcass during evisceration (Bilgili, 1988). Therefore, birds were exposed to pre-slaughter fasting, and their live-weight was taken just prior to slaughter.

The most common slaughtering method used was severing of jugular vein with knife to drain blood. This resembles *halal* system of killing as facilities for humane slaughtering methods (Raj & Gousi, 2000) is not available at CNR farm. The other method used was "stunning" birds by hitting on spinal region between the wings. The feathers were plucked using hard scald plucking method. This involves immersing slaughtered birds in 60 to 65°C water for 2-5 minutes. Feathers can be plucked without tearing or bruising the skin or breaking wing bones. Small incision in the abdomen region along a line from the end of the breast bone to the vent was made. The internal organs including gullet, crop, gizzard, and intestine were removed. Dressed carcass here refers to internal organs removed, head and legs intact, and carcass washed thoroughly. The dressing percentage was calculated using the formula below:

Dressing % = Dressed carcass weight/ live weight X 100

The FCR was calculated as shown below:

Feed Conversion Ratio (FCR) = Total weight of feed consumed/Actual live-weight gain

Data Analysis

Data on feed consumption, growth rate, live weight, and carcass weight were recorded. MS Excel software was used to compile some

part of the data while some are exported to Minitab (version 13) for simple statistical analysis.

RESULT AND DISCUSSION

Nutrient Content and Aflatoxin

Poultry feed contains all nutrients needed to grow muscles, bones, internal organs, fat and feathers. About 65-75% of the total expenditure of commercial poultry farming goes to feeding, therefore success of poultry farming depends mainly on use of balanced but cost effective feeds. Proteins, which are metabolized and converted into various amino acids, are essential for chickens.

Nutrient analysis revealed that KF starter has not met recommended or standard crude protein requirement (Cheeke, 1999; Coon, 2001) by 1.31% while SF starter contain 1.07% CP higher than actual requirement (Table 1). In other words, latter contains 2.38% CP higher than former. It is also evident from Figure 4 that performance of SFG has taken new turn from day 14 to day 20 as CP requirement is highest in the first 2-3 weeks (Lacy, 2001). However, both SF and KF contain slightly higher CP than the standard requirement (Table 1). When compared among the two feeds, SF contains 0.34 % CP higher than KF.

Table : Comparison of nutrients in two feed samples (analyzed at SPAL) as compared to standard nutrient recommendation (Cheeke, 1999; Coon, 2001)

	Samrat Starter	**Samrat Finisher**	**Standard Nutrient Requirement (Starter)**	**Standard Nutrient Requirement (Finisher)**	**Karma Starter**	**Karma Finisher**
Crude Protein	**24.07%**	**20.93%**	**23.00%**	**20.00%**	**21.69%**	**20.59%**
Crude Fiber	5.67%	6.61%	2.5%	2.4%	6.38%	7.02%
Either extract	4.00%	5.85%			3.81%	3.13%
Dry matter	90.09	91.31%			90.26 %	90.27%
Calcium	1.03%	.90%	1.00%	0.90%	0.86%	0.75%
Phosphorus	0.52%	0.49%	0.45%	0.40%	0.58%	0.47%
Potassium	1.85%	0.60%	0.40%	0.35%	1.02%	1.22%
Magnesium	0.03%	0.18%	600mg	600mg	0.04%	0.09%
NDF	20.69%					
ADF	19.77%					

Poultry is highly susceptible to aflatoxin (McDonald, 1992), which is a metabolite of the fungus Aspergillus flavus. Toxic level of aflatoxin, causes decreased body weight and feed intakes, poor skin pigmentation, depletion of lymphoid organs such as thymus and bursa of fabricius and microscopic and histological lesions in the liver (Saxena, 1999). Aflatoxin productions in the feed are because of humidity in the storage and the storage temperature. The relative humidity of 80-85%, moisture concentration of 17%, and temperature of 24-35°C are the optimum condition for aflatoxin production (Saxena, 1999). Laboratory test result from NCAH indicates negative to qualitative aflatoxin suggesting both the feeds were technically safe for feeding broiler birds. The test result is an indication of good quality feed storage system in Karma feed mill (Bhutan), Samrat feed mill (India), and Wangchutaba broiler farm.

Growth Rate

There are number of factors (nutrient content, particle size, palatability etc) influencing growth rate of broiler birds. Studies have shown that broiler gained more weight with increased energy level and had significantly improved feed conversion. If there is protein deficiency in the feed than it results in feed consumption and loss of body weight in adult birds (Coon, 2001). Broilers are normally fed pelleted feed throughout the growing cycles (Lacy, 2001). Chicks are provided pelleted feed that has been crumbled so that it is in pieces small enough for the birds to consume easily. However, both SF and KF were in the form of crumbs and there was no trace of pellets. Physically, SF contained more crumbs than KF which was mainly dominated by fine small crumbs and powdery form. With better CP content and appropriate crumb size seen in SF, it is clear that growth rate is better in SFG birds as compared to KFG birds.

According to Lacy (2001), birds reared up to 42 days grows rapidly from first few weeks of life, peak at 6-7 weeks of age, and then declines as they grow older (Figure 1). In contrary, this experiment showed gradual increase in weight gain and peaked at 4-6 weeks of age (Figure 4).

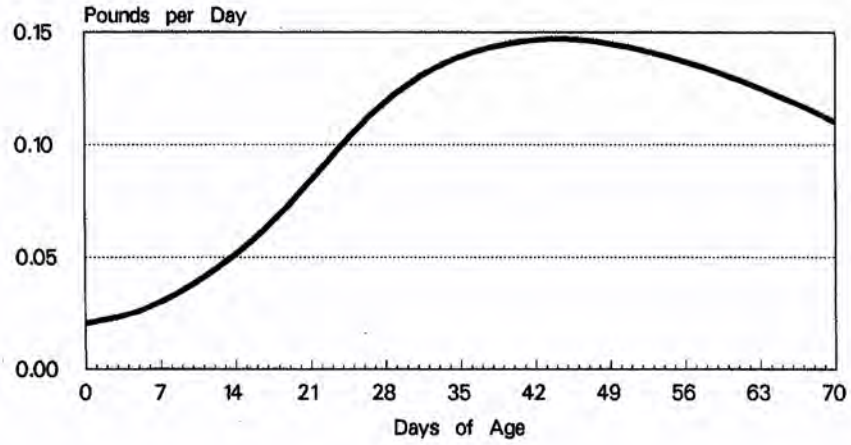
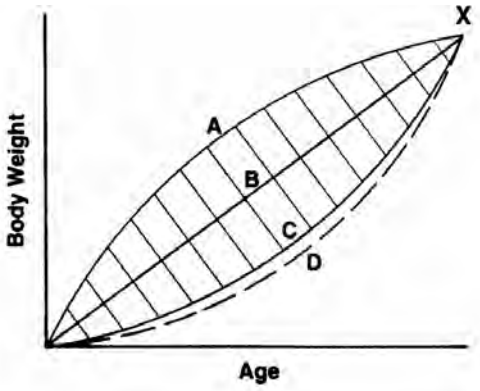


Figure 1: Typical growth rate of broiler at different age. Source: Lacy, 2001

The actual live-weight gain (final live-weight – initial live-weight) in 41 days for each SFG bird is 2.41 kg with daily weight gain of 58.76 gm. On the other hand, actual live-weight gain of each bird in KFG is 2.14 kg with daily gain of 52.28 gm. This may be the fact that CP content of SF is better than KF. The growth curve generated is very much in line with schematic representation of growth curves for broiler chickens suggested by Lesson & Summers (1991) as depicted in Figure 2.

Figure 2: Schematic representational growth curves of broiler chickens. **Source:** Leeson & Summer, 1991



Growth rate of birds in both groups have taken a shape of line C (Figure 3). Both groups had initially slow growth rate but accelerate at some point (week 3) towards projected market weight of 2.0 kg in 42 days. Birds with growth rate of such trend are likely to exhibit a superior feed conversion since its maintenance requirement will be less (Leeson & Summers, 1991). The reason for this reduced maintenance requirement is that at any specific age, prior to projected market weight, the birds had smaller body mass to maintain, and so will need less feed nutrient for this purpose. However, such growth trend would mean increased carcass fat composition, which was also true in this experiment.

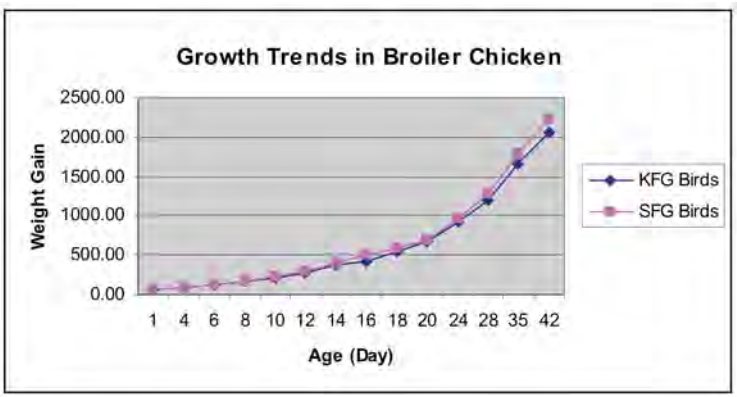


Figure 3: Growth curve of the KFG and SFG.

The statistical analysis of Two-sample *t*-test for final market live-weight of KFG and SFG birds suggest that there is a significant difference (P-Value = 0.000) between the groups at 95% confidence interval. In other words, SFG birds had significantly higher market live-weight than KFG birds. The box plot (Figure 4) generated below is an illustrative indication of the live-weight gain of KFG (KLWt) and SFG (SLWt).

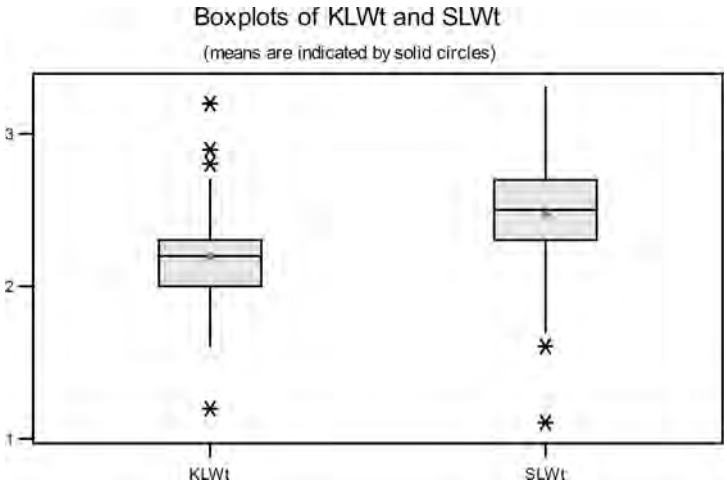


Figure 4: Comparison of final live weight between KFG and SFG.

In addition to this, the carcass-weight of both the categories of birds was compared. The SFG birds had significantly higher ($P<0.05$) carcass weight than KFG group. The average dressing % at 42 days for KFG and SFG was 87.62% and 89.78% respectively. High dressing yield is observed in SFG, which also had higher live-weight. This finding is consistent with several other studies (Souri *et al.,* 1972; Deka & Kalita, 2004), which have observed significant correlation of live-weight with dressed percentage. In short, growth rate, live-weight, carcass weight and dressing percentage were better with higher CP content in the feed.

Feed Efficiency

The cost of feed is the major investment incurred in poultry farming business, which must attempt at faster growth of broilers with excellent Feed Conversion Ratio (FCR). In general, it is said that most efficient poultry farmers are producing broilers averaging 1.45 kg to 1.5 kg at six weeks with average feed conversion ratio of 2.0, and mortality less than 2.5% (Saxena, 1999).

The FCR calculated for SFG is **2.05** and KFG is **2.65.** In other words, amount of feed eaten by SFG birds to gain 1 kg of live-weight is 2.05,

while KFG birds had eaten 2.65 kg of feed to gain 1 kg live-weight. This suggests that animals that have low FCR are considered efficient users of feed. In fact, FCR was better than the standard value suggested by Saxena (1999). The ideal environmental temperature, good housing conditions (air quality, litter management), and aflatoxin free feeds may have been the reasons for good feed efficiency.

Since two categories of feeds were used, FCR alone cannot reveal the efficiency of feed. It is also important to calculate the cost effectiveness of feed used. The total feed consumed in six weeks by 94 birds in SFG is 465.25 kg costing Nu. 6112.21. On other hand, total feed consumed by KFG was 532.99 kg of feed costing Nu. 6350.11. Both from the point of FCR and cost effectiveness of feed, SF has proven to be better than KF. Although, it is not clear how Vencobb broiler birds have been bred, the genetic potential of this strain to convert feed into meat may be another factor contributing to good feed efficiency. There has been steady genetic progress in growth rate of broilers over the last two decades (Nicholson, 1998).

CONCLUSIONS

The performance of broiler birds fed with imported feed was better than the feed manufactured in Bhutan. It was justifiable for private broilers farms or any other broiler farms in Bhutan to import feed from India. However, this experiment does not indicate that KF is a poor quality feed. In fact, it has achieved 2.14 kg live-weight and this is highly acceptable market live-weight at 42 days. To further improve KF, the study recommends following:

- There is a need to increase CP content of in-country broiler starter feed (at least up to 23% CP).
- Physical form (particle size) of feed needs improvement if KF is to attract customers within and outside Bhutan. Studies have shown that feeding pellets made into crumbs as starter diet, and pellets as finisher diet significantly increases live-weight and improves feed efficiency (Yule, 1974; Saxena, 1999; Coon, 2001).
- To further substantiate this experiment, similar studies with

adequate treatment and replicates either by the feed mill(s) of by relevant institutions within Bhutan would be extremely useful.

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Honey Bees In The Foot Hills Of Bhutan: An Untapped Resource

N B Tamang[1]

ABSTRACT

Foothills in the sub-tropical belt of Bhutan are endemic to many species of honey bees. Among them, Apis cerena species is most commonly hived for generations to produce honey.In order to understand the honey production potential of indigenous bees, data on the existing beekeeping practices, honey production, consumption and sale, facilities available and gender involved were collected from five villages of Bhur block, Sarpang and two villages of Phuntsholing block, Chukha.

Results indicated that honey bees are mostly managed in traditional log hives. Annual honey production per hive is about eight bottles (750ml/ bottle) in two harvests. Honey produced is consumed at home and used in treating common ailments. About half (45%) of honey produced is sold helping farmers to generate some cash income. Income generated at the moment is not very significant but home use of honey is contributing to health and well-being of farm families.

Honey bees have been an unfailing partner of rural folks. Apart from improved health and income it also helps to increase crop yield through pollination services. However, available honey bee resources remained to be gainfully utilized for greater benefit of poor and landless. Improved ways of beekeeping is largely unheard and beekeeping method is still primitive. None the less, farmers with long tradition of beekeeping, have adequate experience on traditional beekeeping. Honey production thus can be improved by harnessing traditional knowledge and amalgamating with modern beekeeping technologies.

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Hindrances to enhance honey production are several. Lack of skills on improved ways of beekeeping, periodic migration of bees due to seasonal temperature fluctuation, absconding due to food shortage, disturbance to colonies and pest attacks contribute negatively to honey production. Action research needs to be carried out along with the beekeepers to find ways to curtail migration/absconding and control of pest while imparting them skills on modern beekeeping practices.

KEYWORDS :

Honey bees, *Apis cerena*, log hives, foothills

INTRODUCTION

Foothills in the sub-tropical belt of Bhutan are home for many species of honey bees such as *Apis dorsata, Apis florea, Apis cerena* and *Apis melipona.* Among these species *Apis cerena and Apis melipona* is successful hived for generations to produce honey.

Honey produced is mostly consumed by family member at home and use it for medicinal purpose to cure common ailments. Only some household sell a few bottles as and when there are cash needs at home. Therefore, economic benefit from commercial honey production is yet to be exploited and realized.

Owing to little resources required for beekeeping, improvement of traditional practices could increase honey production and it can be a potential economic activity for poor and landless people to generate cash income to alleviate rural poverty.

Moreover, honey bees are increasingly recognized as an important pollinating agent. Keeping bees is proven to increase yields and profit from crops substantially. For example, the economic value of pollination services in US on the 100 most significant crops is estimated at US$ 1.6-9.0 billion and in Costa Rica there had been 7% increase in coffee production valued at $62,000(API, 2006). Further, Popa (1980) estimated that indirect contribution of honeybees to agricultural production is 10-15 times greater than direct contribution.

However, very little or no efforts have been made to make honey production with indigenous honey bee (*Apis cerena*) a viable enterprise, largely due to unawareness of its importance. In order that the beekeepers learn improved beekeeping methods to increase honey production; improve health and well-being of the farm families; generate of cash income and increase crops production, the livestock research program, Renewable Natural Resources Research Centre (RNRRC) Jakar in collaboration with International Centre for Mountain Development (ICIMOD) initiated research and demonstration on indigenous honey bees.

One of the collaborative activities is to identify potential pockets where beekeeping activities have been a long tradition and select beekeepers interested to expand their activities to supplement farm income. Subsequently, data on existing beekeeping practices, production and marketing of honey, constraints to enhance production and beekeeping activities men and women carry out were collected from the areas identified.

The study had the following objectives:

- Collect data on social set-up and beekeeping facilities available
- Understand the existing beekeeping practices, production and income
- Identify constraints that hinders increased production of honey
- Assess the gender situation among beekeepers

MATERIALAND METHODS

Location of research sites

- Bhur block in Sarpang district (Jhupreydara, Mongargaon,Ghalley goan, Dungkarling and Jaruwa villages)
- Phuntsholing block,Chukha district(Pachudara and Sadhumadhu villages)

Criteria for selection of sites

- Area farmers with long tradition of beekeeping
- At least 25 beekeepers are interested to expand their activities to enhance income

Data collection

Data were collected in multiple stages:

Site visit and farmer/beekeepers' selection

Potential beekeepers in villages of Bhur and Jigmecholing *block,* Sarpang and villages of Phuntsholing *block* in Chukha were visited by researchers and local extension agents. About 27 farmers from each *block* were selected in consultation with local extension agents and field research staff.

Group discussions

Pre-selected farmers/beekeepers were invited to a meeting/discussion at a central location- RNR Sub Centre at Bhur and *Chupen's* (village headman) house at Sadhumadhu. Group discussions were held to assess gender situation among beekeeping households. Details on existing beekeeping practices were also collected using standard format.

Informal discussion

Informal discussion were also held with key informants to validate information on the present beekeeping practices: harvesting time, number of harvest per year, bee pasture/flora available, season and cause of migration/abounding of bees, constraints in beekeeping, use and marketing of honey.

Data Analysis

Data from the individual interviews were entered in a spreadsheet. The answers to the questions were grouped into: numerical data that were averaged; *Yes-No* answers coded and "word" answers that fell into similar pattern were counted manually and when ever practical converted to a percentage. Observations and impressions were described.

RESULTS AND DISCUSSION

Social structure and facilities

Beekeepers in the study area consist of diverse ethnic groups such as Rai, Mongar, Ghalley, Tamang and Subba. These groups except Tamang follow Hinduism. The community is coherent as the people are permanent settler for a very long time. About 15 percent of the households are also headed by female and rest by males.

The villages in Bhur *block* are within 30 minutes walk from the nearest road head. The villages have electricity and rural water supply, telephones, two primary schools and an outreach clinic where hospital staff regularly conducts vaccination campaign. Pachudara and Sadhumadhu villages however is about three hours walk from nearest road head and there is no school and telephone connection.

Farming systems

In both the sites selected, farmers practice rice based farming system. Rice is cultivated in the irrigated terraced wetland. It is transplanted during July-August and it is the most labor intensive among all the farming activities. Rice is used mostly for subsistence. After harvest of rice, mustard and buckwheat is cultivated in some portion of wetland. Maize is also cultivated as dryland crops but generally don't grow well in Bhur but it is a main food crop in Pachudara as there is less area under wetland due to shortage of irrigation water. Millet is grown after harvest of maize. Aracanut, citrus mandarin is the main cash crop. Varieties of vegetables, other fruits such as mango are also grown. Farmers rear livestock such as cattle, goats, sheep, chicken, ducks and bees. The villages have abundant tree/ plantation cover.

Income sources

About 35 percent of the respondents sell citrus mandarin annually (Table 1). It is the main cash crop in the study areas. Farmers who has fruit bearing mandarin orchards are better off than the rest. For 10 percent of farmers, orchard combined with livestock such as goat and

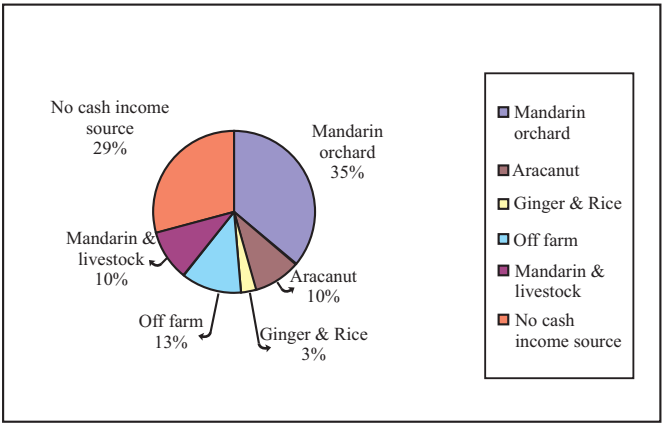
cattle contributes to the household cash. About 10 percent of farm families sell aracanut. Some 13 percent of farmers, who don't have mandarin orchards or aracanut, engage in daily wage off-farm activities to meet household income. Ginger and rice are sold by some farmers for cash while 29 percent of the farmers don't have any ready source of income. They could be poorer than others in a community.

Beekeeping

Beekeeping tradition and use of honey

Beekeeping has been a long tradition in most of the households in the study area with 62 percent of the households keeping bees for honey production. However, keeping honey bee is only a part-time job as only effort made is to make hives, clean them before the arrival of migrating bee and harvest honey periodically.

Table 1. Income sources



Honey is long recognized by local people as medicine to cure sore throat; chicken pox, stomach pain, foot and mouth disease of livestock, wound and so on. Some honey is always retained at home to treat common ailments. ICAR (1990) mentioned that Indian system of medicine belonging to both *Ayurvedha* and *Sidha* extensively use honey as a vehicle for drugs. Further, Dorji and Tshering (1999)

reported that oral drenching as well as application of mixture of honey and molasses on lesion is a common method to treat foot and mouth disease in villages.

Bee flora

There is abundant bee flora in the natural vegetation that blooms during different seasons of the year. The seasonal crops such as maize, rice, wheat, buckwheat, vegetable and fruit trees provide nectar and pollen to bees most of the year. Bees in turn help plants by providing pollination services essential for production of viable seeds for sustainable agriculture.

Types of bees available

Two types of bees reared in the villages: i) *Apis cerena ii*) *Apis melipona*. *Apis cerena* in turn is believed to be of two strains, one strain has yellowish appearance and other type is black. Honey production is believed to be better with yellow ones. ICAR (1990) also mentioned about three strains of *Apis cerena indica F.* One strain is found in the hills are bigger and dark grey, other two strains found in plains are light grey and reddish yellow. .*Apis melipona* a miniature dammar bee locally termed as *putka* are also kept in few households.

Types of bee hives

Log hives are predominant method of hiving bees and constitute about 86 percent of total hives used. It is a piece of a hollow tree trunk, either natural or artificially made. The hollow is covered on both sides with piece of wood and smeared with cow dung. Small hole is made in the middle as a passage for worker bees. The hives are either spread around the homestead if there are many or hung around the house. About seven percent of the respondents keep bees in wooden boxes and three percent in wall hives. Improved hives is being used to keep *Apis cerena* in a few households at Tabji (Drala, Chukha).

Honey production

Average annual honey prouction when harvested twice is eight bottles (750ml/bottle). A colony/hive of indigenous bee produces maximum of seven bottles and minimum of one bottle or even less with an average of four bottles per harvest. This finding is close to earlier estimate of two to four bottles per harvest/ hive in mid-altitude areas of Tsirang and Dagana districts of Bhutan (Dorji, 2001). However, a beekeeper at Tabji reported that eight bottles of honey could be obtained in a single harvest for same bee species managed in improved hive. Thus, use of improve hive is likely to double the yield. *Apis melipona* produce about one bottle honey per hive per year.

Honey harvesting

Bees are harvested using locally made knife. Usually smoke is created inside the hive that drives away the bees and honey is then harvested. The honey once harvested is strained using double layer muslin cloth.

Generally honey is harvested twice in a year, November-December and February-March. Some farmers however harvest three times (February-March, June-July, November-December) some harvest even four times while some harvest only once. Fortnightly harvesting of honey during late spring is also reported as there is sufficient honey flow due to spring bloom. However, it is doubtful whether the matured honey could be harvested in this very short period.

Seven bottles is reported to be obtained during spring harvest in March and low (1-2 bottles) in other seasons. Good harvest in March is attributed to flowering of buckwheat and mustard flower in winter which invariably is considered as best flora for bees. Less production when harvested after monsoon is because bees are unable to go out to collect nectars and pollen during rainy days and is the most food scarce period. Irregular and frequent harvesting also could have aggravated the situation.

Honey sale, income and price

Interview with beekeepers (n =49) revealed that out of 368 bottles of honey estimated to have been produced only 168 bottles (45 percent) were sold in the previous year. Remaining 55% is retained for home consumption. Average income generated was Nu.773 per household. About 21 beekeepers (43 percent) did not sell honey at all as their production is low while others who produce slightly more sell some and keep the rest for home use. At the moment income generated from honey is very negligible probably contributing less than five percent of the household income. However, honey being a natural product, a highly nutritious food with remarkable dietetic and therapeutic properties (Popa, 1980), home use of honey is contributing to better health and well-being of farm families.

Many farmers sell honey at their door steps because production is low and demand for it is often high. Some sell them in open market in nearest town or meet the demand if orders have been placed from towns. Sometimes few farmers take to Thimphu (Capital city) for sale. Price obtained varies from 100-150 per bottle in the locality. *Apis melipona* honey fetches Nu. 800-900 per bottle as it is highly valued for its medicinal property.

Constraints to enhance honey production

Bee migration/absconding

Absconding is departure of all adult bees of a colony from their nest while migration is the regular seasonal movement of bees towards different blockraphical locations (Pratap, 1999). In low-altitude study areas (< 1200 *m asl*), most colonies migrate in April-May when the local area becomes very warm. The migration is towards cooler mountain side in the north. The downward migration takes place in August-September. But in mid-altitude areas (1200-1800 *m asl*) when days are cold in winter, bees migrate towards warmer places in the south and return in spring (Dorji, 2001). It appears therefore that migration is periodic phenomenon for bees based on seasonal weather conditions and it could be an inherited trait. However, provision of

cooler places for bees to live in summer in low-altitude areas and covering hives with jute sacks in winter in mid-altitude areas is reported to curtail migration of bees to some extent. Presence of six colonies of bees in five different households visited which reportedly have not migrated for many years support the opinions.

Bees tend to abscond many a times. Besides human factors such as unskilled handling, disturbance to colonies results in absconding. Farmers attributed following reasons for absconding/migration of bees:

- Heat stress due to lack of ventilation to keep cool in summer
- Food shortage due to complete harvesting before monsoon (June-July)
- Attack by predators such as cockroach, ant, bird, bear and hornet
- Frequent harvesting, unskilled handling and disturbance to hives
- Over crowding of hives
- Non removal of old colonies and dirt periodically
- Development of new queen, division of colonies and in-fighting

Predators and enemies of bees

Farmers reported that ants, cockroaches, birds, bears and hornets are a major threat to bees. Similar enemies of bees including Pine Marten, lice, and fleas have been reported from foothills of Nepal (Shukla, 2000). But it is reported that *Apis melipona* miniature local bees have inherent capacity to safeguard themselves forming a group and can even kill enemies as big as hornet. High value of latter's products and capacity to defend themselves from predators is positive attributes that could be capitalized.

Other miscellaneous constraints

- Farmers still follow traditional crude beekeeping methods
- Traditional hives have no provision for periodic inspection for pest and diseases
- Beekeepers lack skills on modern beekeeping techniques (hive making, bee management, hygienic method of harvesting etc.)

- Loss of production due to non availability of skilled honey harvester in the neighborhood
- Bees are managed with little or no care
- Lack of quality assurance due to irregular harvesting of honey
- No organized group to produce, process and market honey
- Farmers have not recognized beekeeping as an income generating activity
- Livestock extension staff have no formal training on beekeeping

Gender involvement in beekeeping

Assessment of gender situation revealed that there is no social and religious taboo restricting women to carryout beekeeping activities. Men and women share the beekeeping workload equally. Work that needs physical strength such as hive making is usually carried out by men. Similarly, catching and hiving bees and honey harvesting is mostly the responsibility of men.

However, transfer of colonies, inspection and management is done either jointly or in turn depending whether adult male or female member of the family is available at home. After honey is harvested, simple processing techniques such as straining of honey and putting into the bottle, sale of products and utilization of money is the entrusted to female. Both male and female agreed that either sex can attend the training or study visit based on the interest and availability of manpower at home. There are also evidences that beekeeping activities in some households are mostly carried out by females. In the words of Ms. Indra Maya Daurali, who said, "*I carry out all the beekeeping activities as I am the head of the household and my children don't have skills and interest*" (Daurali, *Pers. comm*., 2006). Thus, it can be deduced that women have equal role as men in beekeeping and in fact they are the main purse-string holder for cash earned from sale of honey while males quietly do the work that needs strength and courage.

CONCLUSIONS

Honey bees have been an unfailing partner of rural folks, supporting to improve their health and well-being, generate some cash and also help to improve crops yield through pollination services. However, available honey bee resources remained to be gainfully utilized for greater benefit of poor and landless. Improved ways of beekeeping is largely unheard and beekeeping method is still primitive. General lack of skills and awareness on improved way of keeping bees is hindrance to rapid up-scaling of beekeeping activities. None the less, farmers with long tradition of beekeeping have enough experience on traditional beekeeping. Honey production can thus be improved by harnessing traditional knowledge, amalgamating with modern beekeeping technologies. But full time beekeeping as a main income generating activity will however depend on resources availability, interest of beekeepers and market opportunities for honey and by-products.

As there are no social and religious restrictions against women, they can be encouraged to take an active role in promotion of honey bee activities. Further, coherent society and similar ethnic groups in a community gives opportunities to form beekeepers self-help groups in a longer run.

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Forestry

Bamboo and Cane: Potential for Poverty Reduction and Forest Conservation

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ABSTRACT

This paper examines the resource availability of Neomicrocalamus andropogonifolius (Griffith) Stapleton and Calamus acanthospathus (Griffith), their roles in the household subsistence economy, traditional knowledge, post-harvest practices and species' vulnerability to commercialisation. The gross commercial bamboo growing stock is estimated at 1,925m^3 from the total growing area of 27.4ha. Based on the artisans' knowledge, gross maximum commercial growing cane stocks is estimated at 27 metric tonnes and minimum of 16 metric tonnes from 15.4ha. Annual supply and demand trends from 1995-2003 illustrate diminishing resource supplies. Bamboo and cane enterprise contribute 66% of the gross household incomes and provides employment to 97% of the total households on a seasonal basis and is economically profitable even if the opportunity costs of collection are taken into account. Specialization in the manufacture of high quality finished products is strategy overcome food insecurity and other severe development constraints like access to road and market infrastructures. Middlemen transactions are important but exploit the poorest artisans by paying them lower prices. Bamboo and cane crafts are used for a variety of domestic, agricultural and commercial purposes. Driven by commercialisation, traditional management is tilted towards harvesting with insufficient attention on regeneration according to the principles of sustainability resulting into considerable impact on these species. Elderly artisans say young generation are less skilful in the manufacture of high quality finished crafts tailored to tourist preference and desirability, and initiation of training schemes are necessary to improve quality, standardised harvesting and regeneration and preserve this unique cultural heritage. The vulnerability status of these two Non Wood Forest Products (NWFP)

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was assessed at an overall rank of 22 and 32, indicating moderate and high vulnerability. Further studies and policy and management decisions are needed to conserve and utilize these resources and sustain the local enterprise ecologically and economically.

KEY WORDS:

Poverty reduction, Non-Wood Forest Products, Traditional Knowledge, Forest Conservation, Vulnerability, Commercialisation,

INTRODUCTION

Little qualitative and virtually no quantitative information on the bamboo and cane resources is available including ecology and management. MoA (1997) reports harvesting of bamboo, in particular, *Neomicrocalamus andropogonifolius*, taking place on a substantial scale fuelled by spiralling commercialisation thereby exerting considerable pressure on the supply side with significant impact on the species' and surrounding natural forest ecosystems around Bjoka, Zhemgang District. As a result, the National Women Association of Bhutan (NWAB) points out the irregular supplies of raw material as the cause for abrupt ending of the earlier Panbang based local enterprise. A precautionary principle needs to be exercised with an economic activity based on only one species of bamboo. Flowering and fruiting behaviour of the species and indigenous knowledge for proper planning, domestication and management are unknown. With increased commercialisation, domestication through rhizome and stem offshoots of this bamboo needs to be adapted. Stapleton (1994c) states this bamboo as a climber and requires shade and support of trees and grows in often dense clumps in limited localities characterised by highly fertile soils and abundant rainfalls. This species therefore appears highly vulnerable necessitating understanding of its ecological requirements if domestication is to success. Local artisans reportedly travel long distances in search of harvesting adequate quantities of this bamboo, which indicates its likely vulnerable (MoA, 1997). However, conservation status of *Neomicrocalamus andropogonifolius* and the cane (*Calamus acanthospathus*) used for bangchung-making has never been studied.

Also, little is understood with regard to their roles of bamboo and cane in the household subsistence economy and employment and harvesting and regeneration methods resulting insufficient recognition and accommodation in community and private forestry rules. Because bamboo and cane have been little recognized, the regulations on sustainable harvesting, regeneration and marketing remain largely unclear. Knowing such roles can over-egg the "poverty image" and also could spin-off positive influences on policy-makers to concentrate on prioritised NWFP that holds greatest promises for local and national economies through income generation and concomitantly help conserve forest ecosystems. Conversely, local craftsmen are not fully aware of their crafts economic potential due to limited access to marketing information. If existing areas of this bamboo in the government forest are being managed sensibly, it could make sense to transfer such forest areas as community forestry status after the production of necessary management plan.

This study attempts to assess the resource base sustainability of the bamboo (*Neomicrocalamus andropogonifolius*)and cane (*Calamus acanthospathus*), their roles in the household subsistence economy, traditional uses and knowledge, post-harvest practices and species' vulnerability to commercialisation in order to arrive at further studies, policy and management decisions required for sustainable utilization and conservation of these two NWFPs.

MATERIALS AND METHODS

Description of the study site

Bjoka lies in the Lower Kheng occuping a total geographical area of 195.66 Km^2 and is bordered with Ngangla in the west, Bardoh to north and adjacent Mongar district in the east. Panbang and Tingtibi is the nearest accessible commercial towns requiring about 12 hours and 2-3 days of walk respectively. Local language spoken is *Khengkha* and a mixture of *Sharchopkha* and *Khengkha* depending on the origins. Bjoka is historically a resettlement village populated by migration of peoples from the eastern districts of Bhutan. Total population estimates 1,714 from 139 households spread across 27 villages. Development

infrastructures comprised RNR (Renewable Natural Resource) extension centre, two rural clinics, one basic health unit, primary school and irrigation channel and ten rural water and sanitation schemes.

Land use type constitutes wetland (12 ha) dry land (88 ha) tseri (760 ha), mixed agriculture partly wetland and dry land (738 ha) natural pastures (454 ha) and forest types; broadleaf (16,960 ha) broadleaf with conifers (59ha) and scrub forest (11 ha) (MoA, 2002). Others include; rocky outcrops (149 ha) water spreads (312 ha) and settlements (7 ha). Economy is subsistence-oriented and depends on agriculture and livestock.

Bjoka receives a total rainfall of 1503 mm/yr with a highest of 442mm in July and lowest of 10mm in January (Fig.1). The rainfall distribution pattern is skewed with most rainfalls occurring between the summer months of April to September crucial for new growth and regeneration of vegetation including bamboo and canes.

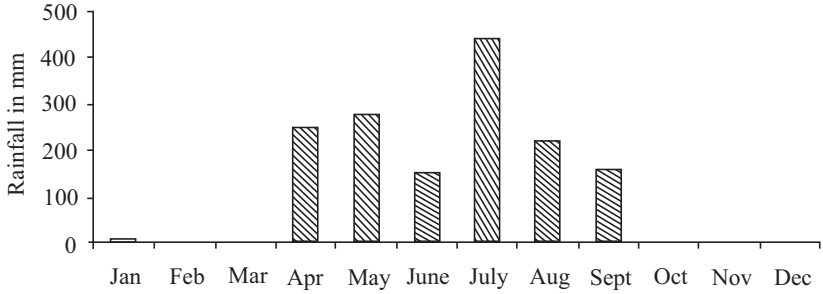


Figure 1: Annual rainfall in Bjoka

Bjoka falls in the warm broadleaf vegetation zone (Table 1) and it is characterised by dominance of principal tree species such as *Altingia excelsa*, *Betula alnoides* ,*Castanopsis indica*, Engelhardtia spicata, Maesia spp, *Ostodes paniculata* and *Macaranga pustulata*. Various bamboo and cane species abound the forests along the moist shady creeks and streams.

Table 1. Characteristics species of the warm broad leaf vegetation zone of Bhutan

Forest type	Characteristic genera and species
Warm Broadleaf Forest	*Alangium chinense, Alnus nepalensis, Altingia excelsa, Betula alnoides, Bischofia javanica, Callicarpa arborea, Castanopsis indica, Cordia obliqua, Dendrocalamus hookeri, Dichroa febrifuga, Engelhardtia spicata, Entada pursaetha, Euodia fraxinifolia, Firmiana colorata, Helicia nilagrica, Lithocarpus elegans, L. pachyphyllus, L. fenestratus, L. dealbatus, L. listeri, Macaranga pustulata, Maclura cochinchinensis, Maesia spp., Mussaenda roxburghii, Ostodes paniculata, Pouzolzia sanguinea, Rhaphidophora eximea, Schima wallichii, Stereospermum personatum, Trevesia palmata, Wendlandia puberula*

Source: *Grierson and Long (1984)*

Bamboos and canes-distribution and characteristics

(a) Bamboo (*Neomicrocalamus andropogonifolius*)

Out of thirty bamboo species recorded in Bhutan, twenty-one species are found growing in the lower, middle and upper Kheng under Zhemgang (Stapleton, 1994d). Out of the twenty-one species, eleven were recorded in Lower and Middle Kheng. *Neomicrocalamus andropogonifolius* (Griffith) Stapleton locally named *Yula* in Khengkha, *Ringshu* in Dzongkha and Sharchopkha and *Langma* in Lhotshamkha is the commercially important bamboo of lower Kheng.

Stapleton (1994) describes distribution of *N. andropogonifolius* as often scrambling from sub-tropical to warm temperate areas restricting to the wetter eastern forests of Bhutan especially around 1,600-1,800m found in conjunction with *Ceplalostachyum latifolum* and *Chimonobambusa callosa*. *N. andropogonifolius* grows often in dense clumps but in limited localities characterized by highly fertile soils and abundant precipitation. These soils are deep brown with sandy clayey to clayey loam texture. *N. andropogonifolius* is a climber that requires the shade and support of trees. Its association is broadleaf associate tree species including *Syzizium, Litsea, Ostodes paniculata, Myria*

esculanta, Castanposis indica, Merisenia semiserata, Maesia chisa, Macaranga postulata, Pentapanax fragrans, Quercus glauca, Engelhardtia spicata, Eurya acuminata, Nyssa javanica, Evodia, Ficus hispida, Altinga excelsa, Exbucklandia populanea, Betula alnoides and Ardenia marcophylla.

The morphological features of the above bamboo is described by Stapleton (1994) and Noltie (2000). The rhizome grows to about 1m long and one to several culms arises from single clump and reaches about 12m in height. The culms are smooth, shiny and narrow with 50cm long internodes that look glossy and green with typical branching from the nodes. Culms sheath are tough and smooth with its apex very narrow and needle-shaped. Leaf sheaths are thin, broad and acuminate and triangular. The inflorescence appear similar to those of small bamboo such as *Arundinaria* but they have six stamens instead of three indicating that they are related to genera *Bambusa* and may represents an intermediate stage in bamboo evolution. The mid-culm buds are tall and narrow. There may be up to eighteen similar branches, or the central branch may be strongly dominant and similar in size to the culm

(b) Cane (*Calamus acanthospathus*)

Canes (rattan) are found throughout Zhemgang with Lower Kheng as the richest repository of canes in the district. Six species of canes belonging to two genera were recorded from lower, middle and upper Kheng of about ten species thought to occur in Bhutan (Noltie, 2000).

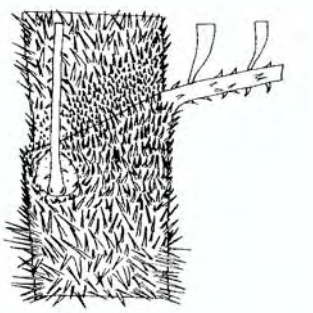


Figure 1. *C. acanthospathus*

Out of the six species, *Calamus acanthospathus* locally named *Krath, Gren* in Khengkha, *Gauribet* in Lhotsamgkha and *Munzi* in Sharchopkha is the commercially important used in conjunction with basket making from the bamboo. It is a solitary stemmed cane with leaf sheaths armed and densely arranged spines and a long spiny flagellum as specialised climbing

organ, which helps to grow high into the forest canopy (Figure 1). Virtually no reliable information on climate and soil physical and chemical requirements of this cane is known within Bhutan and therefore warrants investigation.

DoF (2004) reports on the additional information on flowering in November-December and fruiting in April-June from Nepal. Across the border, it is reportedly growing in the neighbouring Indian states of Arunachal Pradesh, Assam, Meghalaya, Sikkim, West Bengal (MoA, 1997) and Nepal distributed from Terai upto 2000m elevations in semi-evergreen, evergreen and moist deciduous forests (DoF, 2004). However, in Nepal it is reported to grow well in moist grey and red clay soil and in well-drained loamy soil (Amatya, 1997) with associates *like Dalbergia sisso*, *Acacia catechu, Trewia nudiflora, Toona ciliata, Bombax ceiba* and *Albizza species* (DoF, 2004).

Surveys and Data collection

In selecting target respondents for interviews, judgemental sampling was adopted. This was necessary firstly to reduce the cost of a very widely spread sample and secondly to avoid logistical difficulties associated with steep terrains and scattered farm houses. Seeking the assistance from the local administration, households that do not dwell on bamboo and cane handicrafts were excluded. Thus most households engaged in craft making were interviewed constituting 51% males and 49% females. Demography, roles in the household subsistence economy, traditional use and knowledge, post-harvest practices and marketing information were gathered using semi-structured questionnaire. Information from farmers' interest group (producers and artisans) were solicited to consolidate household views on key topics like locations, harvesting and regeneration technique, supply and demand, post-harvest practices and species' vulnerability using Rapid Plant Vulnerability Assessment Scale and checklists and sustainability criteria derived from Watts (1998); Wild and Mutebi (1996); Messerschmidt et al., (2001). Clusters of bamboo from the accessible growing areas were sampled by laying out $100m^2$ temporary plots (Rai and Chauhan, 1998). In each plot, bamboo clumps and associate trees =10cm dbh (diameter at breast height 1.30m) were

tallied. Further from ¼ of the plot, culms per clump, diameter (cm), height (m) and culms quality were assessed. To determine the relationship between fresh and dry weight, culm diameter classes 0-18cm, 18-36cm and 36cm and above were selected. In each diameter class, the utilizable culm length 30cm above ground measured and top, middle and bottom section cut-off, their length measured and fresh weight taken. The weight of bamboo goes on decreasing after collection as they contain lots of moisture and difference between the first weight W_1 (fresh weight) and last weight W_2 (dry weight) calculated to show the amount of moisture loss. The standard weight of bamboo was estimated using the formula $W_1+W_2/2$ (Rai and Chauhan, 1998).

RESULTS AND DISCUSSION

Bamboo and cane resources at Bjoka

Bamboo (*N. andropogonifolius*) and cane (*C. acanthospathus*) growing localities, their approximate areas and time taken to reach these various destinations at the outskirts of Bjoka are given Table 2 and Table 3. Canes are also collected as far as from Khagparang and Tala under Nala geog (sub-district) adjacent to Bjoka. Based on the artisans' knowledge, total bamboo and cane area is estimated at 27.4 hectares and 15.4 hectares respectively. Artisans re-iterated that bamboo and cane collection time increases every year indicating diminishing supplies. The area under Khagparang, Tala under Nala sub-district and Serthang within Bjoka district were unknown

Table 2. Bamboo (yula) growing locations, areas and time taken to reach collection points in these natural forests

Location	**Approximate area[5] (ha)**	**Time taken (hours)**
Tsalati	2.8	2
Phagpakar	1.2	2
Tshakaling	1.2	3
Wagombrag	2.0	2
Wamlathang	2.0	3
Plam	1.6	1.5
Lungtarpong	0.8	2.5
Charsingpong	1.2	3.5
Gongchukhan	2.8	1.5
Phuborong	0.8	2.5
Senglengbrangsa	0.6	2.0
Tachung	0.8	4.0
Phungphungla	6.0	2.0
Kunchungbrogsar	2.0	1.5
Yeamong	0.4	1.5
Bogmo	1.2	2.0
Total	**27.4**	33.5

Table 3. Cane growing locations, areas and time taken to reach collection points in these natural forests

Location	**Approximate area (ha)**	**Time taken (hours)**
Khagparang Tala }	Nala geog Not available	3-4
Phatari	4.0	Not available
Senglengbrangsa	0.6	2.0
Jatshaminplam	2.0	Not available
Serthang	Not available	Not available
Gowalapo Thorcho	7.0	4.0
Kila	1.8	4.0
Total	**15.4**	**13.5**

[5] Estimates based on informants' knowledge during the participatory resource mapping excercise

Potential commercial growing stocks of *N. andropogonifolius* (yula) and *C. acanthospathus (*krath)

Gross commercial growing volume of the bamboo is estimated at 1,925m^3 or 1,604 metric tonnes approximately from the total area of 27.4ha (Table 4). The average number of clumps per hectare is estimated at 4,340 with a sampling error of 40% at 95% confidence level. The number of clumps/ha was multiplied with an average number of 11 culms/clump to estimate the density of 47,740 culms/ha. Out of the average 11 culms/clump, 56% were green sound, 24% dry sound, 11% green damaged, 5% decayed and 4% dry damaged (Table 5). The average height of the highest culms in a clump estimates 14.3m of which, 12.5m or 87% are commercially utilizable (Table 5). The utilizable length of the culm weighed about 2.19 kilograms on fresh weight basis. These figures are used to estimate the approximate commercial growing stocks in respective growing locations.

Table 4. Estimates of gross commercial growing stock of *N. andropogonifolous* (yula)

Location	Area (ha)	Total Nos of culms	Gross commercial & non-commercial standing volume (MT)	Gross commercial standing volume[6] (Metric	Gross commercial standing volume[7] (Cubic meter)
Tsalati	2.8	1,33,672	293	164	197
Phagpakar	1.2	57,288	125	70	84
Tshakaling	1.2	57,288	125	70	84
Wagombrag	2.0	95,480	209	117	141
Wamlathang	2.0	95,480	209	117	141
Plam	1.6	76,384	167	94	112
Lungtarpong	0.8	38,192	84	47	56
Charsingpong	1.2	57,288	125	70	84
Gongchukhan	2.8	1,33,672	293	164	197
Phuborong	0.8	38,192	84	47	56
Senglengbrangsa	0.6	28,644	63	35	42
Tachung	0.8	38,192	84	47	56
Phungphungla	6.0	2,86,440	627	351	422
Kunchungbrogsar	2.0	95,480	209	117	141
Yeamong	0.4	19,096	42	23	28
Bogmo	1.2	57,288	125	70	84
Total	**27.4**	**13,08,076**	**2,865**	**1604**	**1925**

[6] Based on estimate from sampling that only 56% of the gross number of culms are green sound and are commercially utilizable

[7] Assuming that a tonne of this bamboo weighs 1.2m^3 approximately

Table 5. Number of clumps, culms/clump and culms quality observed in the sample plots

Species *N. andropogonifolius*	**Clumps / plot**	**Clums/ clump**	**Culm quality**					**Ht (m)**
			Green sound	Green damaged	Dry sound	Dry damaged	Decay	
Plot 1	28	18	8	2	7	0	1	6.56
Plot 2	45	17	9	4	3	0	1	18.50
Plot 3	30	06	5	0	0	0	1	16.30
Plot 4	55	08	5	0	3	0	0	15.96
Plot 5	59	06	4	0	0	2	0	14.47
Average/ plot	**43.4**	**11**	**6.2**	**1.2**	**2.6**	**0.4**	**0.6**	**14.3**

Fresh weight to dry weight ratio estimates 100:60. The 2-3 years old commercial green culms harbours lot of water and consequent loss seems reasonable. The figures on commercial growing stocks may be treated with a caution as the estimate is based on sampling from few locations where private households have domesticated this bamboo in their tseri land and/or government forests and plantations have reach harvestable stage within a span of 7-8 years. Density of clumps per hectare may vary under natural conditions compared to man-made plantations and sampling from naturally growing bamboo and cane forest locations was virtually constrained by torrential monsoon rains and time constraints.

According to the artisans' knowledge on harvestable cane (krath) quantities per person per acre basis, mean maximum harvestable stock is estimated at 1,745575 kg/ha and minimum of 1,024368 kg/ha. Using these figures the maximum harvestable growing stock is estimated at 26,873 kg or 27 metric tonnes and a minimum of 15,761kg or 16 metric tonnes approximately depending on the availability (Table 6). The sampling errors are relatively high indicating the growing stock estimates as not very reliable. These estimates also do not include growing stocks from Serthang, Khagparang and Tala.

Table 6. Estimates of gross maximum and minimum growing stocks of *C. acanthospathus* (krath)

Location	*Area (ha)*	*Gross commercial[10] volume (kg) Maximum*	*Gross commercia volume (kg) Minimum*
Phatari	4.0	6980	4096
Senglengbrangsa	0.6	1047	614.4
Jatshaminplam	2.0	3490	2048
Serthang	Not available	-	-
GowalapoThorcho	7.0	12215	7168
Kila	1.8	3141	1843.2
Khagparang	Not available	-	-
Tala	Not available	-	-
Total	**15.4**	**26873**	**15761**

Trends in supply and demand of yula and krath

Bamboo (yula) supplies from 1995-2003 totalled 54 metric tonnes against the demand of 106 metric tonnes. It means that about 6 metric tonnes were supplied against an annual demand of 12 metric tonnes. Annual trends illustrates, as demand remain more or less constant, supply has fallen gradually (Fig.2). Several factors were attributed to this decline; amount of rainfall, harvesting techniques and increase number of collectors. Artisans say that abundant rainfalls during heavy monsoons induce profuse regeneration of new bamboo shoots with consequent increase in supplies and vice-versa. When new shoots do not arise artisans' defer collections for 1-2 years allowing mushrooming up of sufficient number of young shoots in the consecutive years and then collection resumes. Elderly peoples points out increase in women and children collectors who lack sufficient knowledge and skills on appropriate harvesting and regeneration methods and tends to cut more immature culms.

[10] The utilizable length of cane stem is about 30m excluding 0.6m (about 2 feet) at the base and about 4m from the top portion. The utilizable stem is then cut into 3m long stems obtaining about 10 pieces and weighs about 5 kilograms altogether.

Figure 2. Trends in supply and demand of *N. andropogonifolius* (yula)

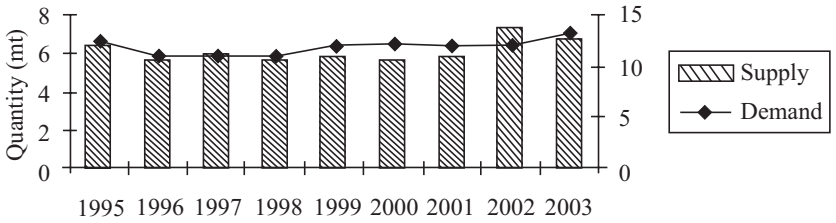
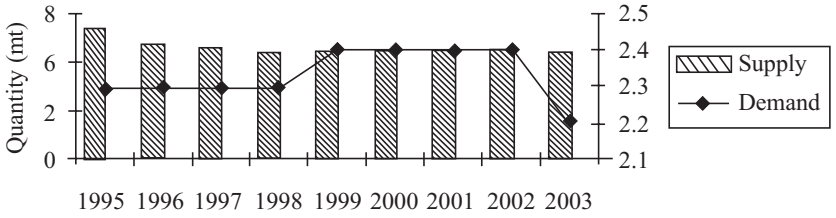


Figure 3. Trends in supply and demand of C. acanthospathus (krath)



Cane (krath) supplies from 1995-2003 totalled 20.7 metric tonnes against demand of 21 metric tonnes. Supply exceeded demand in most cases (Fig.3) exacerbated by commercialisation resulting into significant impact on the species and consequently on supplies.

- **N. andropogonifolius (yula) and C. acanthospathus** (krath) **vulnerability and impact of commercialisation**

Species' vulnerability is a measure of the increased risk of extinction as a result of unsustainable harvesting or any other perturbation(s). The definition of sustainable forest management implies that "the process of managing forest to achieve one or more clearly specified objectives of management with regard to the production of a continuous flow of desired forest products and services without undue reduction of its inherent values and future productivity and without undue undesirable effects on the physical and social environment" (ITTO 1992a, b, 1998; see also Mankin, 1998). While most definitions of "sustainability" emphasises harvesting associated actions can also lower sustainability and increase species' vulnerability. The sustainability of species implies that the impact of anything that affects its natural condition is so low or minimal that the species is not threatened with extinction.

Thus, low vulnerability of species indicates that it is probably sustainable assuming that existing conditions remain in a relatively steady state. For example, if the bamboo and cane of Bjoka is considered as low vulnerable to extinction, then they can be harvested continuously (i.e. provided that the harvest rate is adjusted to result in negligible impact on the structure and dynamics of the plant populations being exploited or on the surrounding ecosystems (Peters, 1994).

Rapid vulnerability assessed the current conditions, trends and practices concerning the commercial harvesting of *N. andropogonifolius* and *C. acanthospathus* from the natural forest. Are these factors inconformity with the sustainability of the species or the resource pressurized to extinction? If the species are vulnerable to extinction, what management actions and/or policy initiatives are necessary? In order to gather these information, farmer interest group were interviewed for tapping their vast field knowledge and experience and evaluated according to the sustainability criteria and indicators derived from Watt (1998); Wild and Mutebi (1996) and Messerschmidt et al., (2001) from serial number 1 to 14.

The results of the analysis are summarized in the 'Rapid Plant Vulnerability Assessment Checklist' in the Tables 7 & 8. The checklist is based on a set of categories within, which specific threats are discussed and scored (ranked). A score of 0 implies nil, 0-13 implies low vulnerability and is no cause for alarm. A score of 14 to 26 indicates moderate vulnerability and remedial actions to reverse the trend may be necessary. A score of 27 to 39 reveals high vulnerability and a high probability of extinction unless immediate actions are taken to halt or reverse the trend. To begin with the vulnerability ranking process, we defined and discussed 14 categories of potential threats. Note that there is partial overlap between some categories. The ranking of relative vulnerability is shown for each category in Tables 7 & 8.

Table 7. Rapid Vulnerability Assessment Checklist for N. andropogonifolius (For each category, rate species' vulnerability by marking with 'v ' in the appropriate column and then summed up columns for overall score)

Column Category	A 0	B Low 1	C Moderate 2	D High 3
Natural conditions and effects on species' life				
Life form and provenance				
(1) Reproduction and longevity			✓	
(2) Habitat			✓	
(3) Growth rate		✓		
(4) Abundance and distribution		✓		
Use and demand				
(5) Part used		✓		
(6) Demand			✓	
(7) Substitutes			✓	
Social, cultural and economic effects on a species				
Basis of Management				
(8) Traditional management			✓	
(9) Scientific management				✓
Commercial effects and other outside influences on a species				
Harvesting and Commerce				
(10) Seasonality			✓	
(11) Commercialization			✓	
(12) Roads	✓			
(13) Grazing			✓	
(14) Other potential threats	✓			
Column totals	0	3	16	3
Grand totals (sum of A, B, C, D)				22
Less than 13: Low vulnerability 14 to 26: Moderate vulnerability More than 27 high vulnerability	Overall assessment of bamboo vulnerability in Bjoka, Zhemgang: Moderate ✓			

Using this ranking system, the vulnerability of *N. andropogonifolius* was assessed at an overall rank of 22: moderate (Table 7).

Table 8. Rapid Vulnerability Assessment Checklist for C. acanthospathus (For each category, rate species' vulnerability by marking with a check 'v ' in the appropriate column and then summed up columns for overall score)

Column Category	A Nil 0	B Low 1	C Moderate 2	D High 3
Natural conditions and effects on species' life				
Life form and provenance				✓
(1) Reproduction and longevity				
(2) Habitat			✓	
(3) Growth rate			✓	
(4) Abundance and distribution				✓
Use and demand				
(5) Part used				✓
(6) Demand				✓
(7) Substitutes			✓	
Social, cultural and economic effects on a species				
Basis of Management				✓
(8) Traditional management				
(9) Scientific management				✓
Commercial effects and other outside influences on a species				
Harvesting and commerce				
(10) Seasonality				✓
(11) Commercialization				✓
(12) Roads	✓			
(13) Grazing			✓	
(14) Other potential threats	✓			
Column totals	0	0	8	24
Grand totals (sum of A, B, C, D)				32
Less than 13: Low vulnerability 14 to 26: Moderate vulnerability More than 27 high vulnerability	Overall assessment of the cane vulnerability in Bjoka, Zhemgang: High ✓			

Using the ranking system, the vulnerability of *C. acanthospathus* was assessed at an overall rank of 32: high (Table 8).

Traditional uses and knowledge on resource management

Life without bamboo is almost unthinkable particularly for the poorer households of Bjoka. Most people live in simple houses built up of bamboo splits and cane leaves. According to MoA (1997) a clear separation can be made between the uses of bamboo for rural domestic

and agricultural needs supporting the subsistence economy and the production of marketable items. Domestic uses are storing various household foods, beverages, stationeries, containers for arrows and sitting mats. Bjoka households use this bamboo more than any other bamboos for weaving distinctive and attractive pattern traditional items used as host of food and beverage containers for commercial purposes (Pradhan et al., 1996; MoA, 1997).

Canes are yet another species used for a variety of purposes. They are used in house roof and fence construction and a range of tying and stitching purposes in combination with bamboo products. Because *C. acanthospathus* yields best quality flexible tying strips, it is highly preferred for all kind of works such as making bridges, ropes, baskets, frames and even walking sticks (Pradhan et al., 1996). Edible succulent shoots are delicacy in Bhutanese cuisine that is increasingly becoming popular these days on a commercial scale.

Product	Who (**v**)	collects	Who uses (**v**)		Month of collection Bhutanese month											
	Male	Female	Male	Female	1	2	3	4	5	6	7	8	9	10	11	12
Bamboo	✓	✓	✓	✓												
Cane	✓	✓	✓													
Firewood	✓	✓	✓	✓												
Fencing poles	✓		✓													
Timber	✓		✓	✓												
Broom		✓		✓												
Flagpoles	✓		✓													
Mushrooms	✓	✓	✓	✓												
Fodder	✓		✓	✓												
Cane shoot	✓	✓	✓	✓												
Damru	✓	✓	✓	✓												
Wild Yam	✓	✓	✓	✓												
Fern shoots	✓	✓	✓	✓												

banned during the season regular harvest on need basis

Figure 4. Forest utilisation calendar of Bjoka

It is important to note the 5, 6, 7 & 8th Bhutanese months are banned for harvesting of this bamboo. According to the artisans, these months constitute main growing season for regenerating new shoots and disturbance during these period is absolutely avoided (Fig.4). Besides, the bamboo forest also supplies other important household products like firewood, fencing poles, house building timber, brooms, flagpoles, incense sticks, fodder for livestock and wildlife, edible cane shoots and vegetables like Damru (*Elastostema platyphyllum*), wild yams and fern shoots.

Bamboo harvesting is organised according to harvesting seasons starting from the 9th to 4th month of the Bhutanese calendar (Fig.4) in accordance with defacto rules and norms. Over the years through experiences, harvesters have developed sustainable harvesting method that ensures regeneration, clump care and protection from fire and cattle (Box 1). During the banned period, if an individual deliberately or in-deliberately breaches the rules, fines are imposed at the rate of Nu.100 per person. The amount of fines levied if substantial are used for public religious ceremonies and lighting butter lamps if relatively smaller amount in local monasteries. Gup[1] and Tshogpas[2] either in presence or absence of forestry personnel draw the informal agreement on community harvesting. A reesoop[3] is usually appointed with a responsibility to watch over illegal activities especially during the banned period.

Box 1

In-situ harvesting and regeneration technique of *N. andropogonifolius*

-2-3 years quality culms are selected for harvesting
- Culms are cut above 2-3 internodes or 100cm from base of the clump
- NOT ALL culms are cut
- Commercial culms are regularly harvested in order to stimulate regeneration of new shoots during the season and to prevent dying of whole clump naturally usually after 12 years

In response to diminishing raw material supplies, efforts are underway by farmers in domesticating this bamboo in shifting cultivation land.

[1] Elected head of the smallest geographical unit of administration
[2] Representative of a village or a cluster of villages
[3] Village forest guard

Using experience they described on-farm domestication and cultivation technique (Box 2). Most farmers' own tseri land averaging 1.2 ha per household and they have necessarily brought these lands under permanent use through bamboo plantations. Raising plantations in tseri seems the best option, as this bamboo requires the shade and support of warm evergreen broadleaf trees with highly fertile soils and abundant rainfall. Unlike tseri with agricultural crops characterised by "boom and doom" production these bamboo-based tseri lands are relatively undisturbed multi-storied and multi-species sub-tropical broadleaf forests emulating "natural agroforestry system" embedding ecological stability. Bamboo clumps grow profusely as perennial under story crop and yields harvestable culms annually provided climatic and biotic factors do not unnecessarily affect regeneration. Harvesting of 2-3 years commercial culms continues with matured culms uncut offering sufficient reserves for inducing new shoots in the next season. Dense over story broadleaf trees and middle story shrubs provide shade and support vital for scrambling by this bamboo. The natural agroforestry system can best be compared as capital endowment, which ensures continue harvest of commercial culms as equivalent to interest in financial terms. The system therefore caters both critical needs of farmers and concomitantly conserves forests vital for sustaining the local enterprise

Box 2

Ex-situ *domestication and cultivation technique for* Yula

* Matured culms with a partial and/or whole clump are uprooted using spade. Care is taken to uproot the rhizomes with a ball of earth intact.
* Rhizome with soils are covered in wet jute/gunny bag to prevent loss of moisture
* Top portions of the culms are cut-off with a sharp knife retaining about a meter long culms from the base of the clump. This prevents loss of moisture by transpiration from leaves and ease of transportation.
* Clumps are planted in a pit that can adequately accommodate its rhizomes without bending or exposing out from the soils.
* Soils around the base of the clump is compacted up to the collar portion
* Planting is done during the 7th month of the Bhutanese calendar underneath trees and forest providing shade and support
* Protection till considered free from browsing by cattle usually requiring 4-5 years are ensured. Culms are ready for harvesting from 7-8 years onwards.

ecologically and economically. Recognising the economic importance of this bamboo and over-harvesting as imperceptibly taking place, decentralised forestry programmes are encouraging expanding its cultivation and management under the community forest initiative. About 15 acres of unproductive tseri lands and 5 acres of community lands have been set aside for plantations. Review of existing management rules is planned and decentralise management under local community user groups. Domestication and propagation of yula will be initiated in five villages under private forestry schemes.

Little is known about the in-situ and ex-situ harvesting and regeneration of *C. acanthospathus*. This cane is harvested as and when required basis (Fig.4). Rattan stems are cut 5 feet above from the base of the clump and only mature stems harvested. Red and green colour indicates maturity of culms. Artisans' reports that seedlings of this cane are rarely encountered inside natural forests and those few regenerated ones need virtual protection from browsing by cattle and other biotic disturbances in initial stage. Its solitary habit meaning that each plant comprises only one stem and harvesting necessarily kills the whole plants unless immediate actions are taken to reverse this trend.

Role of bamboo and cane in the household subsistence economy

Bamboo and cane products accounted for 66% of the gross household incomes followed by sale of cash crops mainly oranges and cardamom 29% and livestock products like cheese, butter and meat 5% (Fig.5). This apparently underscores the importance of these crafts as the main livelihood source needing recognition and support for resource base enterprise development in order to successfully reduce the poverty and secure sustainable livelihoods of these remotest marginalized communities.

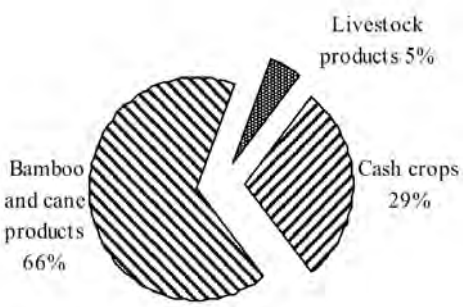


Figure 5. Contribution of bamboo and cane products in household economy

Specialization in the manufacture of high quality finished crafts by these artisans is absolutely necessary to overcome food insecurity and other severe development problems such as access to roads and market infrastructures.

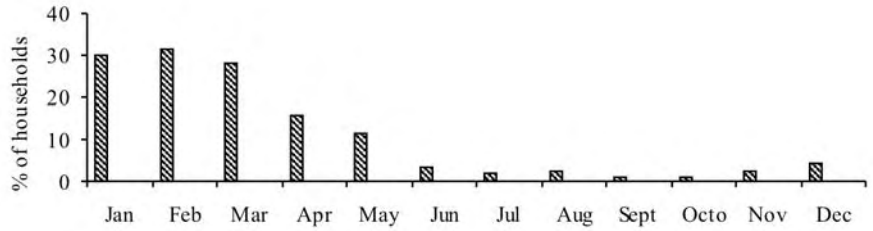
Food insecurity is highly visible especially during the winter months from January to March (Fig.6). 49% of the total households of Bjoka suffer from acute food shortage and hunger (Table 9). To overcome the seasonal food shortage 53% of the households purchases food grains from the nearest Food Corporation of Bhutan

Table 9 . Households' food grain shortage and coping strategies in Bjoka

Geog	No of months with no food	% households with food shortage	Food grain shortage coping mechanisms by percentage of households				
Bjoka			Purchase		Borrow from neighbour	Barter with livestock products	Exchange with labour
			FCB/Market	Neighbour			
Total	1.3	49.1	53.5	16.1	14.3	12.5	3.6

***Source**: MoA (2000)*

Figure 6. Percentage of farm households by food scarcity month in Bjoka



stores and groceries at Panbang or Gomphu Praling, 16% from nearby neighbours, 14% burrows from neighbours, 12% barters with livestock products like cheese and butter and 4% exchanges with labour (Table 9). Cash income generated from the sale of bamboo and cane crafts is directly invested in purchasing basic livelihood necessities. Lack of access roads and limited market outlets remain as main constraints to effective marketing of any agricultural products from these remotest villages.

Economic analysis of bamboo and cane crafts

About 97% of the total households with 139 working class males and 180 females are engaged in weaving handicrafts (Phuntsho 2005). Beside older peoples and to a lesser extent children also weaves as part time works either during days and/or even at nights. Six months starting from December to May is the main working season.

Taking into account the cost of production of regularly woven Nyekayama and Tangkama bangchus[1], approximate net benefits are calculated on a monthly and seasonal basis at the household level. Actual costs incurred are in buying kerosene for fuelling lamps during weaving at nights. About five litres of kerosene are consumed per month costing about Nu.70[2]. Other costs include buying of colours like red, yellow and green from nearby shops or across the border towns costing Nu.390 altogether sufficient to colour 20 pairs of bangchus (Nyekayama 13 and Tangkama 7 pairs). Nu.2 per pair is paid as royalty when bangchus are marketed outside the district. Most households sell their products at doorsteps to middlemen and these individuals usually pay royalties when marketing outsides. Cost of producing 20 pairs of bangchus is estimated at Nu.500 excluding the opportunity costs for collection on a monthly basis. Transportation costs are excluded as most households sell their products at doorsteps to middlemen. Total benefit amount to Nu.1330 with a net benefit of Nu.830 per month per household. Considering the working season of 6 months, net total benefits amount to Nu.4,980 per season per household. Besides, these households also weaves numerous other items such as Lakchung, Bata, Baikor, Tshey zaim, which are not taken into account in the analysis as these products are woven on demand basis. These products are also relatively expensive. For example, a household manufactures about 30-40 pairs of Lakchung and 20 pairs of Bata earning Nu.3,432 per season adding up the total income to Nu.8,412. From this simple cost-benefit analysis, it can be concluded that bangchu weaving is economically profitable even if the opportunity cost of collection are taken into account.

[1] Small baskets usually made out of *N. andropogonifolius* used as host of food and beverage containers
[2] Nu. 44.25 is equal to 1 US$ (official exchange rate as on 2005)

High quality finished bamboo products making requires special skills and are acquired after much practice. Elderly people say young generation are less knowledgeable and skilful resulting dilution of rich cultural image of rural Bhutan. In order to successfully preserve this unique national heritage, initiation of training schemes on the manufacture of high quality-finished products including hands-on-practice on standardizing sustainable harvesting and regeneration techniques and business and entrepreneurship skills with necessary support from the concerned Government, NGOs and private agencies should receive priority

Marketing and pricing policy

In the earlier days, NWAB-led cooperative organised marketing in collaboration with local administration. Products manufactured were collectively channelled to outside markets through Panbang as the main outlet. Artisans say that products fetched good prices as high quality-finished products were marketed mostly. Major shortfalls of this group were; few beneficiaries excluding women and children trained in the manufacture of high quality-finished products, financial vacuum after the ending of WWF support and inability to absorb inferior quality products. Since non-functioning of the cooperative, products are almost entirely channelled by middleman these days. Middlemen are crucial in the transaction of crafts from this remotest place but appearing untimely is problematic at times. Artisans say both high and low quality-finished products are on board for marketing these days.

Price varies according to the different types and sizes of bangchus and other numerous items manufactured. Figures 7, 8, 9 and 10 illustrate the middlemen[12], artisan[13] and finally the tourist price[14] according to types; Nyekayama, Lakchung, Baikors, Tangkama, Bata and Dagama and sizes; large, medium and small. Other products like Tshey zem fetches even higher prices (Fig.10). Considering the middlemen price

[12] Price household/individuals receive from middlemen at their doorsteps in Bjoka

[13] Prices household/individuals receive after having transported the products by themselves and sell in Thimpu

[14] Price commercial agencies like handicraft emporium and private shops receive from visiting foreign tourists in Thimphu

received at household doorsteps as baseline price, outside district prices of most products are substantially higher. For example, the tourist prices are more than twice the price artisans receive after having transported their products to Thimphu even if the transportation costs are taken into account. By selling products at doorsteps, artisan loss substantial profit margin, which goes into the pockets of middlemen and commercial dealers. Commercial handicraft dealers say middlemen often increase prices.

Export price tags could potentially be increased further if simple value-adding tasks such as finishing and labelling of products are performed in improving the quality of products.

Figure 7. Price of Nyekayama and Lakchung bangchu according to large, medium and small types

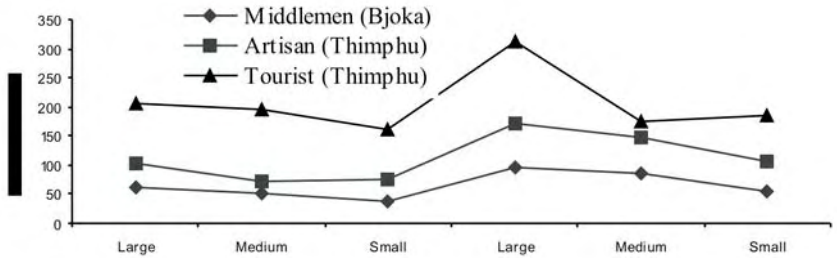


Figure 8. Price of baikor and tangkama bangchu according to large, medium and small types

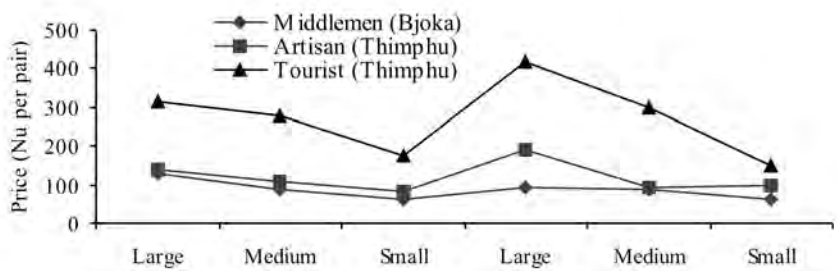


Figure 9. Price of bata and dagama bangchu according to large, medium and small types

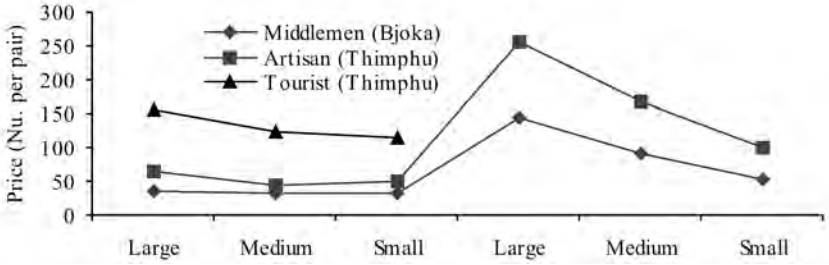
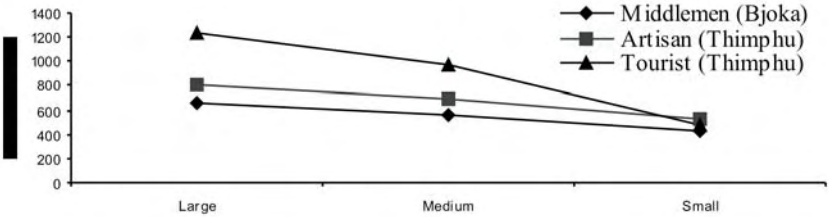


Figure 10. Price of tshey zem bangchu according to large, medium and small types

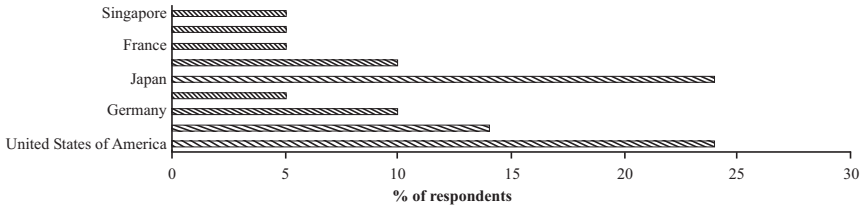


It is apparent from above that the local artisans are grossly underpaid and amount earned do not commensurate with drudgery and poor living standards faced by many artisans.

Demand for bamboo and cane products

Market survey unveils that 24% of bamboo and cane products are purchased by the Japanese tourists and another 24% by the Americans, 14% by tourists originating from the United Kingdom and 10% each from Germany and Switzerland, 5% each from Austria, France, Australia and Singapore (Fig.11). These products are exported as souvenirs to relatives and friends back home. Commercial dealers say tourists prefer buying smaller bangchus/other items that are culturally rich than bigger ones for ease of packaging and showcasing culture. Tourists' back home, use these products as cultural exhibits, trays for snacks, papers, and holders for stationeries like pens and pencils.

Figure 11. Visiting foreign tourists buying bamboo and cane products according to the country of origin.



CONCLUSIONS

In view of the diminishing resource supplies, further studies and policy and management decisions are needed to conserve and utilize these resources and sustain the local enterprise ecologically and economically.

Plantation establishment trials of *N. andropogonifolius* possibly in combination with *C. acanthospathus* should be initiated in areas that are characterised by highly fertile soils and abundant precipitation in improving accessibility and supplies. These long-term studies should include flowering and fruiting, climate, soils and silvicultural requirements and also incorporate genotypes conservation from other locations within the country to safeguard its genetic base in case if the Zhemgang genotype flowers and dies. The current harvesting trends and practices from the natural forest need to be regulated without unnecessarily impinging on the regenerative ability of these resources within the framework of formal community organization and management under the community forestry initiative or common property resource management regimes after the production of necessary management plans. Notwithstanding domestication and cultivation under the private and community forestry programmes and use of substitute like *C. leptospadix* in order to reduce the harvesting pressure on this solitary stemmed cane should be encouraged. Bamboo growth under the " natural agroforestry system" provides both critical needs combined with long-term conservation goals desired by farmers, foresters and policy-makers and can potentially reward in the

advancement of community forestry programs in the local context. Encouraging this bamboo-based production system also reinforces the policy of permanent use of shifting cultivation land and diversification of income sources for economically disadvantaged farmers.

Bamboo and cane products contributes 66% of the gross household incomes necessary for maintaining food security and mitigating other severe development problems like access to roads and market infrastructures and is economically profitable even if the opportunity cost of collection are taken into account. This apparently underscores the potential of these resources to trigger off rural development by prioritising and promoting as income generating activities in the local forestry development programmes and plans providing right incentives if forestry is to justify its pro-poor policy and contribute effectively to overall poverty reduction goals. Initiation of training schemes for young peoples to learn the necessary skills for manufacturing high quality and culturally rich finished products, standardizing harvesting and regeneration practices, increasing value-added benefits by developing processing technologies, product diversification and improving market information through formal institutionalisation of the local enterprise is necessary in preserving this unique cultural heritage, reducing poverty and securing sustainable livelihoods.

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Vegetation succession and soil recovery in the abandoned field at Tshokothangkha in Nahi, Wangude.

PemaWangda[1] & Masahiko Ohsawa[2]

ABSTRACT

Vegetation succession and change in soil chemical properties in the abandoned fields were studied in Tshokothangkha village at Nahi, Wangdue. The sampling plots include a series of fields starting from current year cultivation to 20 years of fallow, with nearby climax forest used as a control. The floristic composition comprised of 37 woody species (16 evergreen broad-leaved, 21 deciduous broad-leaved, and one pioneer conifer), and 107 herbaceous species. The vegetation succession starts from pioneer annual herbs in the early stages of fallow (0-1 year) to perennial herbs (1-3 years) followed by seral trees (5-20 years) and to climax trees. Floristically, number of species increased from 25 herb species in a current crop field to 45 in 1-year fallow, then dropped to 15 in 20-year fallow, and further decreased to 14 species in the nearby climax forest. On the other hand, number of tree species was high in the early seral forest with 17 species in six-year fallow and decreased to seven species in 20-year fallow to increase again slightly to 13 species in the climax forest. After 20 years of fallowing, maximum height, maximum diameter at breast height, and total basal area of tree-layer community attained, respectively, 13.2 m, 14.5 cm, and 42.1 m^2/ha. These values are above 60 % of the maxima found in the climax forest. After burning dry biomass, soil acidity decreased to pH 6.5, while available phosphorus increased to 40 mg/kg. Total soil organic carbon and nitrogen started to recover during the seral-stage (1-8 years) and stabilized at almost initial level after ca. nine years of fallowing. Based on the recovery of floristic composition, aboveground biomass, and soil properties, it can be concluded that abandoned field reached its normal state of more than 60 % at an abandoned period of nine to 12 years.

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KEY WORDS:

Abandon period, Floristic composition, Succession, Soil conditions

INTRODUCTION

In Bhutan, shifting cultivators normally are sedentary population with their own cultivated land. These farmers largely depend on shifting cultivation due to steep topographical terrain, which is not suitable for permanent cultivation. Usually farmers help each other from field preparation to crop harvesting. The shifting cultivation cycle starts when the trees attain ca. 6-20 m height in 9-12 years of fallow period. The trees and bushes are felled down during the months of January to mid February coinciding with the 12th month of Bhutanese lunar calendar before the noxious weeds and herbs invade the field (personnel communication with farmers of Yurung, Chungkhar of Pemagatsel 2003). Most of the trees are cut to the ground, while a few matured canopy trees are kept. The main stems of the felled trees are used in fences, firewood, and sometimes as timber, while branches and other residue parts form a fuel-bed for burning after letting them to dry two to three months (Personnel communication with farmers 2003). Fuel breaks/fire lines are prepared beforehand to prevent escape of fire to the nearby forest. Burning of dried biomass starts in the months of March to early April and usually lasts two-three days. Interestingly, burning is usually followed by spring rain, which helps to enrich the soil. Some parts of residue biomass such as branches of hardwoods (*Lithocarpus elegans, Castanopsis tribuloides, Schima wallichii)* are used to prevent soil erosion by placing them along the steep gullies, particularly, by the farmers of Pemagatsel, eastern Bhutan, and said to be effective in soil erosion controls (Personnel communication 2003).

The present study was conducted to evaluate ecologically the practice of shifting cultivation or abandonment of agricultural fields under the natural condition of Bhutan. Specifically the study focuses to investigate vegetation succession and soil recovery under series of fallow periods with climax forest as a control.

MATERIALS AND METHODS

Study site

The present study was conducted in Tshokothangkha, one of the four villages in Nahi block, Wangduephodrang district, west-central Bhutan (Fig. 1B). Topographically, the study area includes gentle to steep slope within an altitudinal range from 1700 m to 2000 m a.s.l. facing south-east. Tshokothangkha village has only 11 households with an average family size of six members. Each family keeps certain number of cattle (ca. 8 cattle/household) for milking, plowing and for cow manure. The major land use type is mainly dry land cultivation including tseri/pangzing. Farmers also keep kitchen garden, a few household developed apple orchard, and mushroom cultivation. They grow maize, millet, barley, potato, chilly, oat and wheat crops. Besides forest provides wide range of natural resources such as timber, prayer flagpoles, firewood, water, pasture for cattle grazing, litter for cattle bedding etc. Namgyel (1995) identified 107 wild plant species of popular use along with 22 species of edible mushrooms. Several researchers noted that forest is an integral part of villager's livelihood in Nahi and were managed sustainably (Namgyel 1995; Pradhan 2002; Wangda et al. 2005).

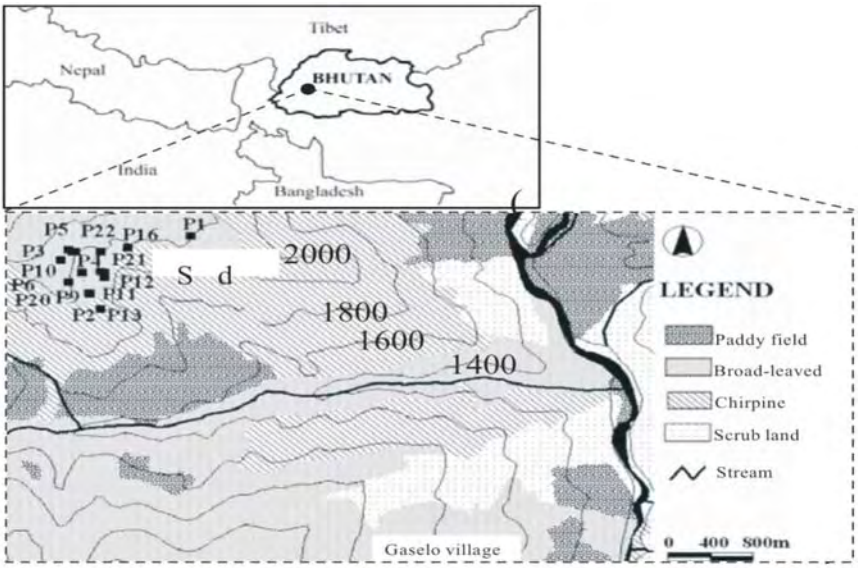

Figure 1. Map of Bhutan and study site; (A) location of map of Bhutan along the Himalayan range, (B) land-use map of the study area located in west-central Bhutan with sampling plots in Tshokothangkha village. Weather station in Gaselo village was also shown in the map, which is located ca. 3 km from the present study site.

Climate

Climatic data (precipitation, air temperature, air relative humidity) of Gaselo village (1800 m a.s.l.) was used in the present study. It is the nearest village having weather station, which is located about two-hour walk (ca. 3 km) to the present study site (Fig. 1B). The annual mean air temperature is 14°C with a maximum mean air temperature of 21.6°C in July and a mean minimum air temperature of 7.8°C in January. The annual relative air humidity is 79 % ranging from 73.4 % in January to 84.3 % in August. The mean total annual precipitation is 810.1 mm, and 60 % of it is received during the summer months of June, July and August while January, February, and December are the driest months getting only ca. 3 % of the total precipitation. Walter's climate diagram clearly shows the contrasts between dry (Jan-Mar and Nov-Dec) and wet (Jun-Aug) periods in the climatic pattern of the study area (Fig.2)

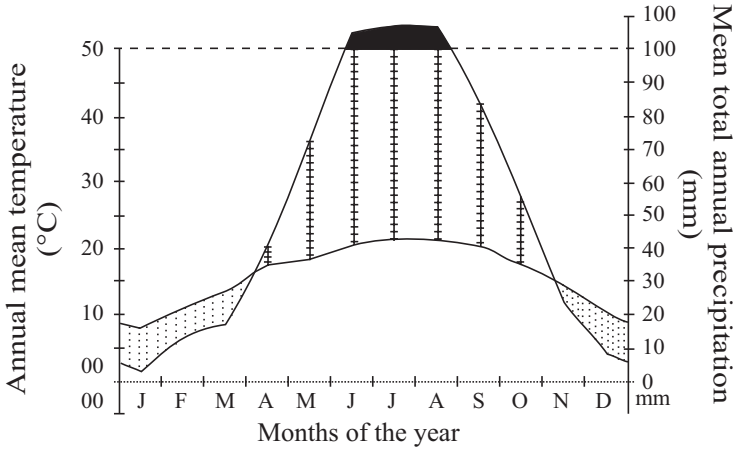

Figure 2. Walter's climate diagram of Gaselo village, which is the nearest weather station to the present study site under similar topography and vegetation types. Winter (Nov-Feb) and early spring (Mar) months are dry and summer monsoon months (Jun-Aug) are humid and wet while late spring (May) and early autumn (Sept.) months receive fairly good precipitation. (Data from 1986 to 2000, Ministry of Agriculture, Bhutan).

Environmental data: meteorology and soil moisture

Meteorological data (precipitation, temperature, relative humidity) was collected from the meteorological section of the Ministry of Agriculture, Thimphu, Royal Government of Bhutan. Additionally, instantaneous air and soil temperatures were also measured by digital thermometer ($DELTA_{SK\text{-}200\,MC}$, Sato Keiryoki MFG. Co., Ltd.) during the field survey. Soil moisture content was measured using Hydro-sense (CD 620 + CS 620) (Campbell Scientific Australia Pty. Ltd.) bearing 12 cm and 20 cm probes.

Field survey and plot lay out

With the help of local farmers, we estimated the age of fallow fields, which was then additionally confirmed by counting branch tiers and growth rings on available cut stumps. After site identification, 12 sampling plots (quadrates of 10 m by 10 m) were established in the field. The fallow age of the sampling plots ranged from current crop fields to 20-years of fallow with nearby climax forest as a control. For sampling the herbaceous-stage, we set up a transect of 10 adjacent square plots with 1 m on a side. In each plot, herbaceous plants were identified, the maximum natural height (H, cm) measured, and the coverage (%) estimated for calculating aboveground biomass, relative dominance and species richness.

Tree inventory included measurements of all the tree individuals attaining a height of 1.3 m and above. Each individual tree was identified and diameter at breast height (DBH, cm) measured. We used measuring pole (15 m) as well as digital hypsometer for measuring of: (1) total height (H, m), (2) height of the lowest living branch (H_B, m), and (3) height of the lowest living foliage (H_L, m). For regeneration survey, saplings ($0.5 = H < 1.3$ m) and seedlings (< 0.5 m) were recorded and their age estimated by counting branch tiers and/or bud-scale scars.

Nomenclature of plants followed Flora of Bhutan; Vol. I Part 1, 2, 3, Vol. II Part 1, 2, 3, Vol. III Part 1, 2 (Grierson, A.J.C. & Long, D.G. 1983-2000), Flowers of the Himalaya (Polunin & Stainton 1984),

Concise flowers of the Himalaya (Polunin & Stainton 1987), and Flowers of the Himalaya, A supplement (Stainton 1988).

Data Analyses

For the herbaceous-stage, we used volume as a species abundance measure. Volume was calculated as the height of tallest individual multiplied by the percent coverage of each species. Then we calculated the relative dominance of each species (RD %).

For the forest-stage, tree inventory data were processed to obtain basal area (BA cm^2/area) from DBH data. Then we calculated the relative proportion of each species' basal area (RBA, %), which was used as an abundance measure. Dominant species in each plot were determined by dominance analysis (Ohsawa 1984; Kikvidze and Ohsawa 2002). Species diversity index (H') was calculated by using Shannon & Wienner equation and species evenness (J') was calculated by Pielou equation (1969).

The checklists of floristic composition were prepared using pivotal tables of MS Excel. The processed data was then analyzed for the relatedness of plots using cluster analysis and detrended correspondence analysis (DCA) by PC-ORD version 4 computer based software program.

Soil and litter sampling

Litter and soil samples were collected from the forest floor from 0.5 m by 0.5 m plots. We distinguished litter, fermentation-humus and soil surface A-layer. Litter and soil samples were measured for the fresh weights (FW) and oven dry weights (ODW) obtained at 85°C for 48 hours. Samples were then analyzed at the Soils and Plant Analytical Laboratory (SPAL), Semtokha, Bhutan. Soil pH was measured in suspensions of 1 : 2 : 3 of the soil : distilled water : 1M KCL using a PHM 83 automatic pH meter. Total nitrogen (N) was extracted and converted into ammonium form by micro-Kjeldahl digestion with H_2SO_4 and a Se-based catalyst. Ammonium-N and nitrate-N are extracted by shaking with 0.01M $CaCl_2$ for two hours. Organic carbon

was measured by the Walkley-Black method of low temperature oxidation with acidified $K_2Cr_2O_7$ and titration of the excess dichromate.

RESULTS AND DISCUSSION

Results

Vegetation succession along time series of abandonment fields

We started data analysis with examination of distribution patterns of life forms and found that annual herbs dominated the early stage of shifting cultivation but decreased gradually after development of tree canopy on fallow fields (Fig. 3A). The decreasing annuals were substituted by perennial herbs along increasing fallow period (Fig. 3B). In the tree-layer stage, seral trees revealed a humped-back distribution with high numbers of individuals in the mid-fallow stages (10-20 years), which decreased on both sides towards late and early fallow ages of shifting cultivation (Fig. 3C). On the other hand, the shade tolerant climax tree individuals increased in number towards late stage of shifting cultivation indicating stabilization of forest communities (Fig. 3D). Based on the quantitative vegetation data, the floristic composition of the study area composed of 37 woody species of 16 evergreen broad-leaved (five trees, 11 shrubs), 21 deciduous broad-leaved (six trees, 15 shrubs), one pioneer conifer tree, and 107 herbaceous species (43 annuals, 64 perennials) (Appendix 1, 2). On the basis of standardized relative abundances of all the species (including herbs and trees), four successional stages can be distinguished in shifting cultivation: (1) annual herb-stage (0-1 year), (2) perennial herb-stage (2-3 year), (3) tree seral-stage (>5 year), and (4) climax forest-stage (Fig. 3B). The annual herb-stage was dominated by *Persicaria nepalensis, Bidens pilosa,* and *Fagopyrum dibotrys.* The perennial herb-stage dominants were of *Artemisia vulgaris, Anaphalis*

busua, *Prunella vulgaris* and *Rubia cordifolia*. The pioneer and seral tree species that dominated between five to 20 years of fallowing were *Viburnum cylindricum* (evergreen)*, Swida oblongum, Indigofera dosua, Rhus chinensis* with associated shrub species of *Rubus ellipticus* (evergreen)*, Rosa sericea,* and *Berberis aristata* (evergreen). Sometimes even climax species appeared in the early stage of fallow fields when protected from grazing. For example, in six year fallow field of the present study we found evergreen climax species of *Quercus lanata,* and deciduous *Quercus griffithii,* mixed with broad-leaved understory species. This particular field was protected from grazing and could experience successful sprouting and regeneration of climax species (Appendix 2). The nearby climax forest was dominated by *Castanopsis tribuloides, Q. griffithii, Q. lanata, Pinus roxburghii* with evergreen understory shrubs of *Symplocos dryophilla, Daphne bholua, Eurya acuminata* and *Myrsine semiserrata* (Fig. 3E).

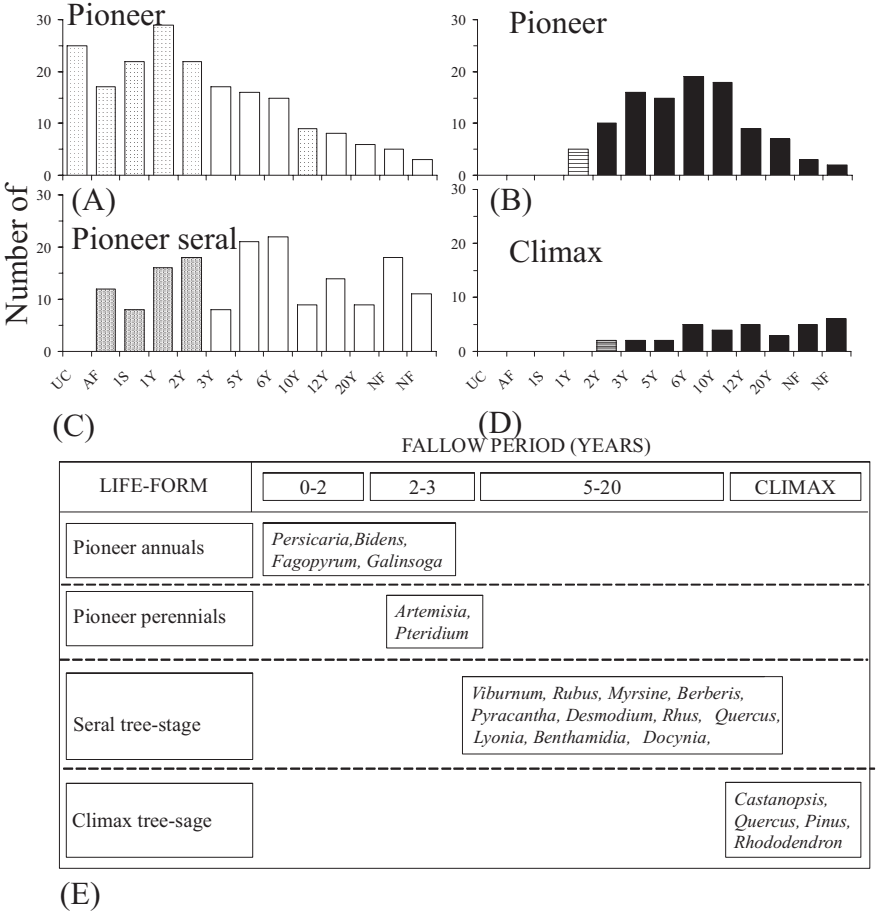

Figure 3. Floristic succession along increasing fallow period; (A-D) individual distribution pattern of life-from along the time course of shifting cultivation, and (E) four successional stages of shifting cultivation with dominant species. (UC=under cultivation, AF=after fire, Y=year, S=season, NF=natural climax forest).

Community structural development

The plant community height during the herbaceous community stages of both annuals and perennials in the early stages of fallow (0-3 years) increased from 0.6 m of *Pteridium aquilinum* in the cultivated field to ca. 3 m of *Artemisia vulgaris* in the 3-year fallow and further increased

to 5 m (*A. vulgaris*) under the seral trees. However, the height of herbaceous species decreased to ca. 1.3 m (*Lespedeza* sp.) in the climax forest (Fig. 4A). At the tree-layer stage, the seral trees reached a height of 3.5 m (*Viburnum cylindricum*) after five years and steadily increased to 13.2 m of *Rhus javanica* after 20 years of abandonment, which is about 60 % of the tallest tree height recorded (*Quercus griffithii* 22.0 m) in the nearby climax forest (Fig. 4A). Similar to the height, diameter at breast height also increased from 2.3 cm of *Pyracantha crenulata* at 5-year fallow plots to 14.5 cm of *Rhus javanica* after 20 year of fallowing (Fig. 4B). Likewise, the total basal area of trees also increased from 0.3 m^2/ha after 5-year fallowing to 42.1 m^2/ha in 20-year fallow, which is 62.5 % of the maximum 67.4 m^2/ha totaled in the nearby climax forest (Fig. 4C). The stem density (applicable only to the tree-layer stage) increased from 164000 stems/ha in the 5-year fallow to 324000 stems/ha in 12-year fallow and then decreased to 10600 stems/ha in 20-year fallow (mostly dominated by seral trees). The density was smallest in the nearby climax forest (5900 stems/ha, Fig. 4D). Stem density and total basal area were inversely related to the duration of fallowing thus indicating that the late stage of fallows attain climax forest features with relatively low stem density of large diameter class trees. The volume equivalent of herbaceous biomass was relatively low after fire and sharply increased in the current year due to crop biomass. The volume of herbaceous weeds indicated their high biomass in the early stages of shifting cultivation (0-2 years), which then decreased after entering the tree-dominated stages until the climax forest.

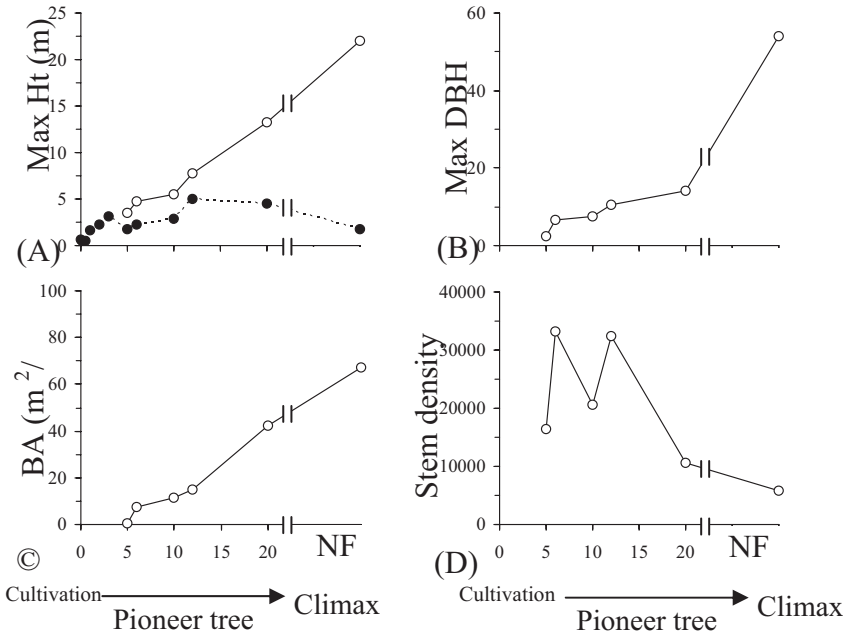

Figure 4. Fallowing dynamics of vegetation communities: (A) maximum height (note: ○ = maximum height of tree community, and ● = maximum height for the herb community), (B) maximum diameter at breast height, (C) total basal area, and (D) stem density.

Regeneration pattern under series of shifting cultivation fallows

Based on the quantitative analysis of seedling and sapling (density), the floristic composition of fallow regeneration consists of 44 tree species belonging to 29 families (Appendix 3). The life-form spectrum consisted of three evergreen broad-leaved trees, 11 understory evergreen shrubs, eight deciduous broad-leaved trees, 28 deciduous shrubs, and two pioneer conifers. The life-form spectra of fallow regeneration accords with the life-form composition of tree layers (Fig. 3C, D; Appendix 2, 3). After one year of abandonment, regeneration of shrubs started with deciduous serals such as *Indigofera dosua, Viburnum mullaha, Zanthoxylum armatum,* and evergreen shrubs such as *Rubus ellipticus, Berberis arsitata* (Appendix 3). Understory

evergreen broad-leaved shrubs (*Ligustrum indicum, Myrsine semiserrata*) and deciduous pioneer trees of *Rhus javanica, Quercus griffithii, Docynia indica, Callicarpa arborea* started to appear in the second year fallow. Three to five years old fallow fields were dominated by evergreen understory species *Viburnum cylindricum*, and deciduous tree serals such as *R. javanica, D. indica, Morus alba*, *Swida oblonga, Benthamidia capitata, Randia tetrasperma, Zizyphus incurva, Coriaria nepalensis, Elaeagnus parvifolia,* and *Erythrina arborescens*. Climax tree species of *Quercus lanata, Acer oblongum,* and *Quercus griffithii* seedlings started to appear after six years of fallowing. Similar seedling and sapling composition was recorded also in the climax forest with additional seedlings of canopy species *Castanopsis tribuloides* and *Rhododendron arboreum*. Two pioneer conifers of *Pinus roxburghii* and *P. wallichiana* were also found both in the fallow fields and under the canopy of climax trees.

Species richness and floristic recovery

Measurements of diversity found clear trends over fallowing years (Figure 5). The number of herb species increased from 25 (16 annuals, nine perennials) in the cultivated field to 30 (16 annuals, 14 perennials) in current year fallow and further increased to 45 (22 annuals, 23 perennials) in one-year fallow (Fig. 5A). The dominating species were annual herbs of *Fygopyrum dibotrys, Bidens pilosa,* and perennial herbs of *Pouzolzia hirta, Solanum* sp., *Strobilianthus* sp. and *Pteridium aquilinum* (cf. Fig.3E). The number of herbaceous species started to decrease after three years of fallowing from 25 (12 annuals, 13 perennials) to 15 (4 annuals, 11 perennials) in 20-year fallow plot and further decreased to 14 (2 annuals, 12 perennials) in the climax forest (Fig. 5A, E). The dominant herbs between three to 20 year fallow periods were mainly perennial species of *Artemisia vulgaris, Prunella vulgaris, Imperata cylindrica, Thalictrum* sp., *Carex nubigena*, *Anaphalis busua*, *Arundinaria* sp., and *Yushania microphylla* under the canopy of seral trees and climax trees (Appendix 1). For trees, high number of species was recorded during the early seral tree-stage: 16 species after five years and 17 species after six years of fallowing, mostly deciduous pioneer species (Fig. 5B, Appendix 2). The species richness decreased towards late fallow (10-20 years) to eight species

after 12 years and to five species after 20 years of abandonment, but increased again to 13 tree species in the nearby climax forest (Fig. 5B). Likewise, Shannon's diversity index for the herb layer showed its maximum in one-year fallow field (H'=4.7), decreased towards the pioneer tree seral stage (H'=3.4), and further decreased in the climax forest (H' =2.8). Similarly, the diversity index for the tree layer, varied from 0.9 at early stage of shifting cultivation to 2.9 after six years and to 2.3 in the climax forest.

Looking at species accumulation curves, it becomes evident that the rate of species accumulation is rather high (Fig. 5C,D). Herbaceous species accumulated much faster during the first decade of fallowing, and reached the number of 98 already in the 12-years fallow, which is a 93.3 % of the total species number accumulated including the climax forest (105 species, Fig. 5C). Then species accumulation slowed down sharply, with only two and five new species added to the 20-year fallow and the climax forest, respectively. The accumulation curve of shrub species reached near-maximum levels similarly fast (after 10 years of fallowing), and leveled towards the climax forest (Fig. 5D). Several deciduous pioneer shrubs that were common early (5-10 years) such as *Desmodium elegans, Lonicera ovovata, Zanthoxylum armatum, Docynia indica* disappeared after 12 years contributing to fast species turnover (Fig. 5F). Tree species accumulation was also marked by a sharp increase by reaching near-maximum values after 12 years of fallowing, and then tapering towards the climax forest (Fig. 5D,F)**.**

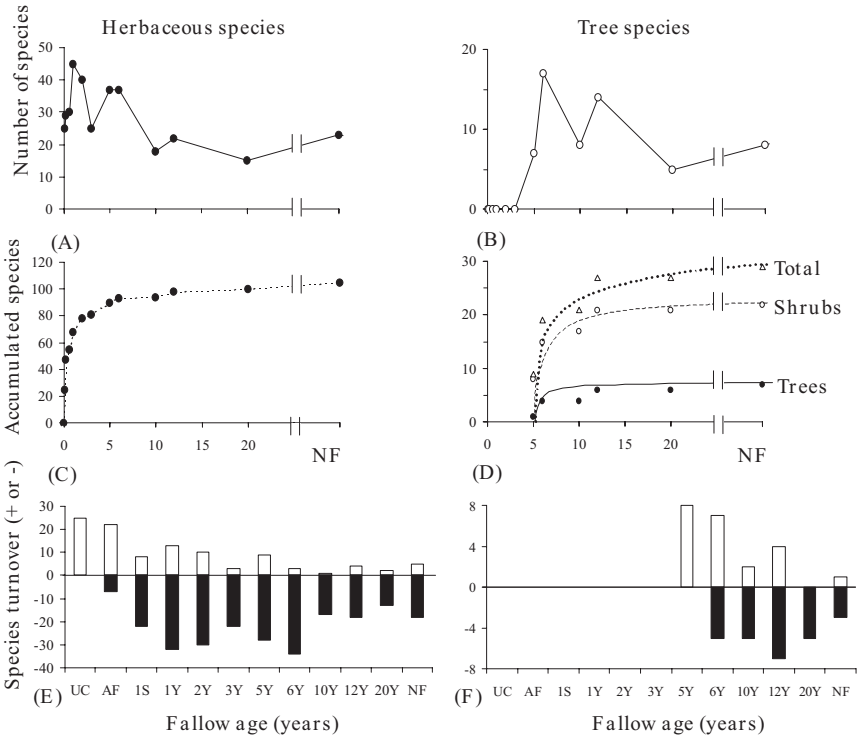

Figure 5. Species richness and floristic recovery; (A, B) species richness, (C, D) accumulation curves, (E, F) species turnover of herbs and trees along the course of shifting cultivation. (UC=under cultivation, AF=after fire, 1S=one season fallow, Y=year, NF=climax forest).

Change in soil chemical properties along the series of fallow fields

One of the benefits of shifting cultivation is burning the dry biomass that recharges the soil and facilitates growing of fallow vegetation after cropping. The changes in soil properties were found closely related to the time of abandonment. At the initial phase of shifting cultivation (0-3 years) soil was neutral (pH = 7), but decreased gradually during the fallowing years. The most acid soil was found in the nearby climax forest (pH = 5; Fig. 6A). Similarly soil organic carbon (C %) was found relatively high after fire (ca. 10 %), but decreased during the early fallow stages (Fig. 6B). Yet it increased again with the increase in above ground biomass of pioneer trees during 5-20 years of fallow

almost reaching its initial level. Total nitrogen showed a similar trend: it was relatively high (0.5 %) after fire, and subsequently decreased (to 0.2%) during the early stages of shifting cultivation (Fig. 6C). Then it increased again (to. 0.5 %) under pioneer tree serals in the 6-year fallow plot, but was slightly less (ca. 0.4 %) in the climax forest (Fig. 5C). Accordingly, high C/N ratio equal to 20.3 was observed after fire, which subsequently decreased to 13-14 during the cropping and early stages of fallow. The reduced C/N ratio at the early stages of shifting cultivation was recovered after six years, and was stable (16-19) after 10 years of fallowing. C/N ratio after 20 years of fallowing was 19.3, which is close to the value 21.4 found in the nearby climax forest (Fig. 6D). Available phosphorus increased sharply (ca. 48 mg/kg) after the fire and fluctuated between 9 to 40 mg/kg during the early stages of shifting cultivation, then steadily decreased to about 10 mg/kg after five years of abandonment (Fig. 6E). Ca/Mg ratio, which is an indicator of leaching, was high (7.0 to 9.0) (Askew 1964, Hans 1994) during the cropping and early stages of shifting cultivation, and tended to decrease steadily from 6.2 after 10 years of fallowing to as small value as 2.0 found in the climax forest (Fig. 6F).

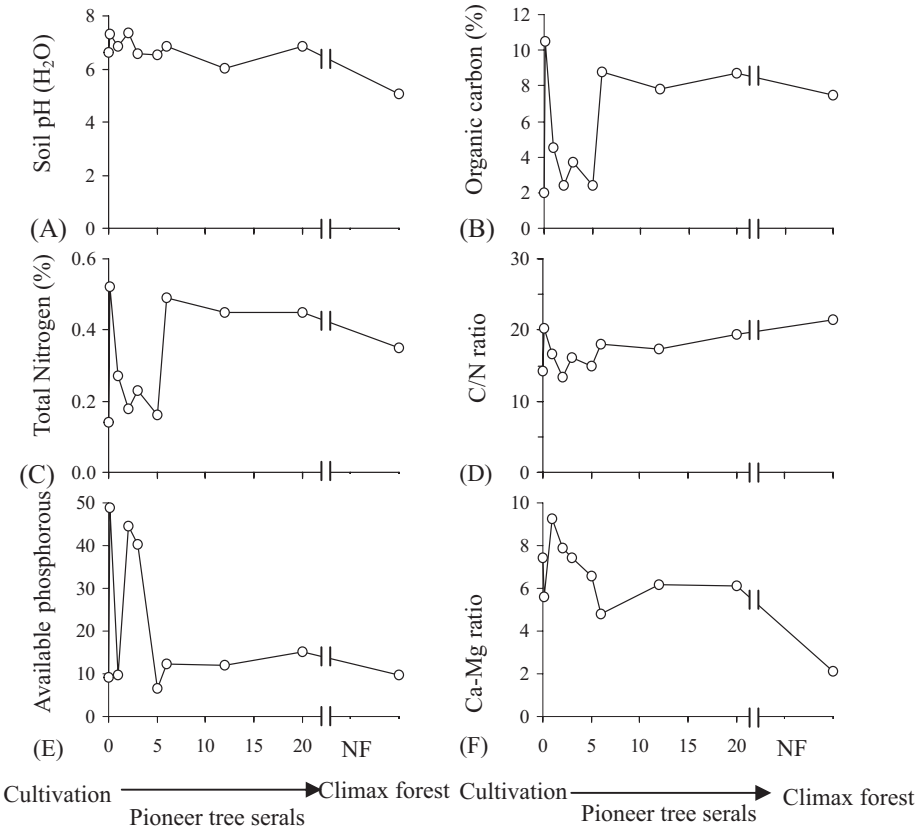

Figure 6. Soil chemical properties along the fallow succession from cultivation to climax forest; (A) soil pH (H_2O), (B) soil organic carbon (%), (C) total nitrogen (%), (D) C/N ratio, (E) available phosphorous (P mg/kg), and (F) Ca/Mg ratio.

Discussion

Floristic recovery in the abandoned fields of different fallow ages

Farmers usually graze their cattle in the fallow fields dominated by palatable annual herbs during the early stages of abandonment (farmers interview 2003). Droppings of the cattle fertilize the soil and probably facilitate invasion of *Artemisia vulgaris* and *Pteridium aquilinum,* which suppress the annual herbs after second year of

fallowing. Probably the unpalatable herbs *Pteridium aquilinum* and *Artemisia vulgaris* further facilitate the establishment of pioneer tree seedlings in the older fallow fields. Accordingly, after five years of fallowing, the height of pioneer trees exceeds 1.3 m and the seral trees start to invade. Further the succession continues towards climax forest. After nine years, the maximum height of trees already exceeds 10 m, and the preparation for shifting cultivation can be started by felling pioneers and sprouts of seral and climax trees. The felled wood serves as an alternative source for fencing, firewood and fuel-bed, which otherwise would need to be extracted from the natural forest. The first year cultivation normally yields good harvest, but subsequently the yields decrease if cultivation is continuous. However, farmers as a traditional practice of rule, cultivate for one or two years only and then move to another site letting the fallow to rest nine to 12 years before returning to its cultivation (Personnel communication with Buli farmers 2003). Hence, from the ecological as well as farmer's management points of view, shifting cultivation is sustainable. It can continue if maintained within the critical fallow length of ca. 9-12 years and if the population of the area stays below the critical density of 10-20 persons per km^2 (Whitmore 1998).

Community structural traits along different stages of fallow field

Forest dimensions (maximum height, maximum diameter, total basal area, stem density) revealed clear recovering processes from pioneer tree to seral to climax trees along increasing fallow period. After ca. 20 years of fallow period, the maximum height of *Rhus javanica* reached 13.2 m, which is already over 60 % of the tallest tree recorded in the nearby climax forest (*Quercus griffthii*). Similar trends were also reported from other shifting cultivation areas of Bhutan (Ohsawa et al. 2002). In particular, the maximum tree height reached 35 m after 20 years of fallowing, which is 78 % of the tallest tree (45 m) found in the nearby climax forest in Tali-Buli, Shemgang, Southern, Bhutan. Similarly, the maximum height after 20 years of fallowing reached 20 m, which is 55.3 % of the recorded tallest tree (37 m) in the nearby climax forest in Chungkhar, eastern Bhutan, (Wangda et al. 2005). However, at our study site the forests grew less vigorously compared to other sites mentioned above, as judged from smaller increments in

height and basal area of trees. These differences can be explained by significantly more humid conditions at other sites (higher soil moisture content, higher precipitation). Tali-Buli in Shemgang (1580-1860 m a.s.l.), and Chungkhar in Pemagatsel (1700-1900 m a.sl.) receive, respectively, 1563.4 mm and 1947.0 mm precipitation annually, whilst our site at Gaselo village near Nahi (1700-2000 m a.s.l.) gets only 810.1 mm. Measurement of soil moisture content also revealed differences between these three sites. Soil moisture content ranges between 36.7 % in 6-year fallow field to 23.6 % in the climax forest of Shemgang (October 2002), and 34.4 % to 44.4 % in Chungkhar (June 2003), whilst only 9.6 % to 12.5 % in Nahi (April 2004). Obviously, forest grows weaker under drier conditions. Similar results were reported by Lawrence & Foster (2002) from the Southern Yucatan, Mexico, where precipitation and soil characteristics contributed to variation in vegetation structure such as woody basal area after 25 years of fallowing.

Soil properties

The gradual decline in soil pH from neutrality to acidity may be explained by the effect of burning. Probably, nutrient cations replace proton ions due to intensive heating thereby raising the soil pH. In any case, burning makes the soil phosphate more available for the cultivation (Nye & Greenland 1960). Although other elements were less abundant in the soil compared to phosphorus, they accumulated through the succession. Soil organic carbon was relatively low in the early stages of fallow and gradually increased with fallow period and reached its highest level after ca. 16 years of fallowing. More importantly, soil nitrogen also increased from the time of abandonment approaching its maximum level after 10 to 16 years, and then remained steady towards climax forest. On the other hand, available phosphorus was high after fire during the current year of cultivation. Apparently, shifting cultivation helps to maintain a nutrient-rich soil, where the nutrients are distributed almost evenly to a depth of ca. 50 cm below soil surface, whilst in the nutrient poor soil, high amount of nutrients and high concentration of roots are distributed superficially (Jordan 1985).

CONCLUSIONS

The study did not find any major impact on the vegetation in terms of species structural traits (maximum height, diameter, basal area, species richness, stem density), nor on soil chemical properties (pH, C %, N %, available phosphorous, Ca/Mg ratio). We conclude that this practice is ecologically sustainable if the fallow periods are maintained for 9-12 years. The vegetation succession shows a fast recovery from early herbaceous-stage (annuals, perennials) between 0 to 3 years, followed by seral tree-stage (5-20 years), and finally approaching to climax forest (Fig. 7).

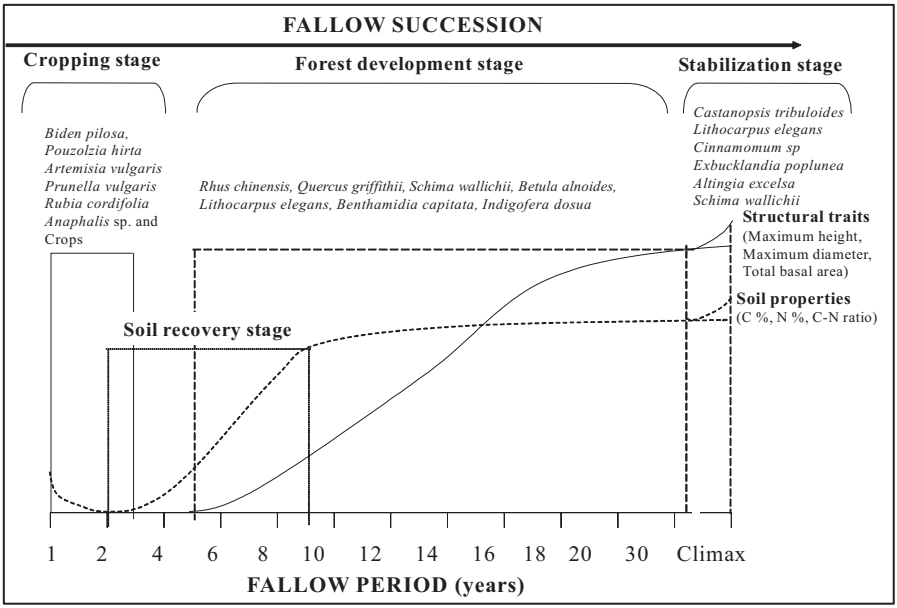

Figure 7. Thematic representation of the shifting cultivation system in Bhutan based on vegetation succession and soil recovery along the time series of shifting cultivation fields in Shemgang (southern), Pemagatsel (eastern) and, Nahi (west-central) Bhutan.

The vegetation requires about 12-20 years to recover more than 60 % of the climax forest features, and the soil recovers its properties for the first decade of abandonment. Whitmore (1998) also reported that nutrients accumulate most rapidly for the first 8-10 years to reach its

initial level in the tropical regions. The concentration of mineral nutrients in tree parts descends in the following order: leaves > twigs > branches > trunks. Most of the leaves and branches are restored in the first few years of fallow ages incorporating a larger part of mineral nutrients into the ecological cycle. Burning of the aboveground biomass makes these nutrients available to the crops, and although nitrogen and sulphur are volatilized in smoke, other nutrients remain in ash and are available to crop plants after rain.

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Appendix 1. Floristic composition of herbaceous species in the study sites. (RD = relative volume, UC = under cultivation, AF = after fire, Y = year)

SPECIES	FALLOW PERIOD (Years)												
	UC	AF	1S	1Y	2Y	3Y	5Y	6Y	10Y	12Y	20Y	NFS	NFS1
ANNUALS	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD
Fagopyrum dibotrys	24.3		6.3										
Persicaria nepalensis	16.3		6.3	1.1	4.8								
Biden pilosa	13.9		6.3	28.2	26.3	0.0		0.4					
Brassica juncea	11.0												
Galingsoga parviflora	5.8		6.3	0.0									
Oxalis corniculata	0.6	0.1	6.3	0.6	0.3	0.0	0.0		0.0				
Amaranthus viridis	0.2		1.6		0.0		0.0						
Chenopodium album	0.1		3.1	0.1				0.1					
Physalis divaricata	0.1												
Canabis sativa	0.1					0.0							
Poa annua	0.0	0.6	3.1	0.0									
Euphorbia heterophylla	0.0												
Crassocephalum crepidioides	0.0			0.0						0.1			
Commelina benghalensis		3.4	4.7	1.7	0.4			0.1			0.1		
Malva parviflora		1.6											
Siegesbeckia orientalis		1.3	1.6		0.2						3.2		
Swertia bimaculata		0.2		0.2		0.2			0.0				
Coriandium sp.		0.2		0.0	0.1	3.5	0.1						
Vigna sp.		0.1											
Hordeum vulgare			3.1										
Ageratum conyzoides			1.6		0.1								
Cynoglossum furcatum			1.6	0.7	0.2	0.0	0.1						
Verbascum thapsus			1.6	0.1		0.0							
Strobilanthus sp.				1.0	3.6			6.0		1.2	73.5	11.2	42.9
Galium aparine				0.6	0.4		1.0	1.0	0.0			2.6	
Sonchus sp.				0.5		0.0	0.0						
Veronica javanica				0.5	0.1								
Mazus delavayi				0.2	0.0								
Solanum nigrum				0.1									
Gnaphalium affine				0.0		0.0							
Digitaria ciliaris				0.0									
Solanum khasianum					0.1								
Kyllinga squamulata					0.1			1.2		0.0			
Tagetes sp.						0.4							
Vicia hirsuta						0.0							
Hydrocotyl							0.0						
Impatiens sp.							0.0						1.0
Selinum sp.									0.0				
PERENNIALS	72.3	7.6	53.1	35.8	36.9	4.1	1.2	8.7	0.1	1.3	76.9	13.8	43.9
Pteridium aquilinum	14.9		4.7						2.8	5.3			
Solanum (Potato)	11.8												
Carex nubigena	0.3	1.9	4.7	0.1	0.9	0.1	0.6	7.3	0.4	4.0	8.1	0.8	0.4
Pouzolzia hirta	0.4	23.8	3.1	1.2	2.1	3.0	0.7	8.7		0.0	0.6		
Clematis buchananiana	0.1	1.2		0.1	0.2		0.0	0.4					
Prunella vulgaris	0.1		7.8	0.8	0.5	0.1	0.3	0.8	0.0				
Geranium nepalense	0.0	0.1	6.3	0.1	0.9	0.4	0.2	0.1	0.0	0.0	0.5		
Cynodon dactylon	0.0		1.6			0.0							
Paspalum distichum	0.0		1.6	0.3				1.0					
Gerardinia sp.	0.0												

Appendix 1. Continued.

SPECIES	FALLOW PERIOD (Years)												
	UC	AF	1S	1Y	2Y	3Y	5Y	6Y	10Y	12Y	20Y	NFS	NFS1
PERENNIALS	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD
Phylanthus urinaria	0.0	0.9		0.0			0.0	7.0				27.8	
Artemisia parviflora		14.9	1.6	20.3	30.7	89.3	58.3	7.2	95.9	87.7			
Thalictrum foetidum		14.8		1.0	0.1			0.1					
Lespedeza sp.		8.2					1.7					7.0	
Salvia lanata		5.9		0.8	5.4		0.1	0.2	0.1	0.1	7.2	0.1	
Dioscorea sp.		4.1	1.6	0.0	0.6			3.5		0.0		0.3	
Elsholtzia sp.		3.9	1.6	0.1	2.3		0.6	4.0		0.1		0.7	
Polygonatum sp.		3.9			0.0		0.1			0.1			
Arisaema sp.		3.2		0.2	0.1		0.0	0.2				0.4	
Juncus sp.		2.6											
Utrica sp.		0.8			0.0								
Leucas ciliata		0.6		4.2	0.4		1.2	0.8					
Viola indica		1.2	1.6	1.1	1.4	0.0	0.6	0.2	0.1	0.0	0.3	0.1	
Potentilla sp.		0.3	1.6	0.1	0.1	0.3	0.4	0.2	0.0	0.2			0.1
Fragaria nubicola		0.0		0.0	0.5	0.1	0.6		0.0				
Iris clarkei		0.0		0.3				6.7		0.6		4.9	
Anaphalis busua .			3.1	33.0		0.1	0.3		0.0			0.2	
Ranunculus chinensis			3.1				0.1						
Nepeta clarkei			1.6	0.0								1.5	
Rumex nepalense			1.6										
Cyperus cyperoides				0.2									
Oxytropis sp.				0.1			0.4					0.4	
Onosma sp.				0.1									
Hypoxis aurea				0.1			0.6					0.1	
Hedychium coccinecum				0.0				7.1					
Rubia cordifolia					13.8	0.1	0.2	0.9	0.0		0.6	0.3	
Eupatorium adenophorum					1.3	1.5		1.7	0.4	0.0	1.2		
Boenninghausenia albiflora					0.9								
Imperata cylindrica					0.7	0.6	28.7	1.0					11.7
Ophiopogon planiscapus					0.1			2.7			2.1		11.3
Aconitum sp.					0.0			2.7					
Asparagus racemosa					0.0			0.1			0.3		
Ajuga lobata						0.3							
Inula cappa							1.8	0.9				6.0	
Stachys sericea							0.9						
Ainsliaea latifolia							0.1	0.4	0.0	0.0		1.5	15.2
Equisitum sp.							0.1						
Gentiana sp.							0.0						
Oplismenus sp.							0.0	0.7	0.0	0.1	0.9		3.3
Arundinaria sp.								13.7					
Yushania microphylla								11.2					
Rubia himalaica										0.4			
Botrychium sp.										0.0			
Hedera helix											0.9		0.7
Aconogonum molle											0.5		
Cymbopogon sp.												29.9	
Lepisorus sp.												2.8	
Dendrobium sp.												1.0	
Ligularia sp.												0.4	
Smilax sp.													7.7
Polystichum sp.													4.9
Pteris creatica													0.3
Hypericum sp.													0.3
Attyrium sp.													0.2
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100

Appendix 2. Floristic composition of tree layers from 5 years fallow to climax forest stage. (RBA = relative basal area, Y = year, NFS = climax forest)

SPECIES	FALLOW PERIOD (years)						
	5Y	6Y	10Y	12Y	20Y	NFS	NFS1
EVERGREEN BROAD-LEAVED TREE	RBA	RBA	RBA	RBA	RBA	RBA	RBA
Quercus lanata		13.0				13.5	24.1
Rhododendron arboreum						23.0	12.9
Castanopsis tribuloides							9.0
Myrica esculenta							1.2
Rhododendron barbetum							0.3
EVERGREEN BROAD-LEAVED SHRUB							
Viburnum cylindricum	55.6	0.4	97.2	31.7	51.6		0.2
Pyracantha crenulata	21.6	0.5					
Rubus ellipticus	4.1	0.5	0.0	0.7			
Berberis aristata	1.0	4.0			0.7		
Myrsine semiserrata		1.9		1.0		0.1	2.1
Berberis asiatica			0.2	1.4			
Daphne surel				0.5			
Meliosoma simplifolia						0.0	
Eurya acuminata							1.8
Symplocos dryophila							0.3
Daphne bholua							0.0
DECIDUOUS BROAD-LEAVED TREE							
Rhus chinensis	8.6		0.2				
Rhus javanica		4.1		1.9	33.0		
Lyonia ovalifolia		5.9				4.9	4.3
Quercus griffithii		3.1				35.3	43.2
Docynia indica		1.2					
Carpinus viminii							0.4
DECIDUOUS BROAD-LEAVED SHRUB							
Indigofera dosua	4.9	45.0		16.6		0.0	
Desmodium elegans	4.1						
Berberis aristata	1.0	4.0			0.7		
Rosa sericea		9.5	0.1				
Lespedeza sp		4.2	1.4	0.6			
Benthamidia capitata		2.3	0.4	13.1	13.4		
Lonicera ovovata		2.2					
Viburnum sp		2.1					
Zanthoxylum armatum		0.3					
Viburnum foetidum			0.5				
Swida oblonga				12.2			
Viburnum mullaha				5.8	1.4		
Colquhounia coccinea				0.8			
Phyllanthus urinaria				0.1			
CONIFEROUS TREE							
Pinus roxburghii				13.7		23.3	
TOTAL	101	104	100	100	101	100	100

Appendix 3. Floristic composition of seedlings and saplings of the fallow fields including nearby climax forest. (RD = relative density)

SPECIES	FALLOW PERIOD (years)									
	1Y	2Y	3Y	5Y	6Y	10Y	12Y	20Y	NFS	NFS1
EVERGREEN BROAD-LEAVED TREE	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD
Quercus lanata					2.2				44.8	3.3
Acer oblongum					1.1		1.5			
Castanopsis tribuloides										0.7
EVERGREEN BROAD-LEAVED SHRUB										
Rubus ellipticus	27.8	22.6	0.9	1.4	1.1	1.0	1.5			
Berberis aristata	5.6	7.5		9.5	1.1	30.9				2.0
Ligustrum indicum		7.5				0.5				
Myrsine semiserrata		1.9	1.3		23.9	18.1	65.0	77.9	23.1	62.1
Viburnum cylindricum			61.1	37.8	1.1	4.9	3.5		0.8	1.3
Pyracantha crenulata			0.5	2.7						
Osyris lanceolata			0.3		1.1				1.4	
Ilex crenata					3.3					
Daphne bholua						0.5	3.6			5.2
Symplocos dryophila								1.5		3.9
Gaultheria fragrantissima									1.4	
DECIDUOUS BROAD-LEAVED TREE										
Rhus javanica		28.3	0.8	12.2	13.0	1.0	1.9			
Quercus griffithii		7.5			8.7			2.9	23.1	21.6
Docynia indica		1.9	3.1	13.5	1.1	7.8				
Callicarpa arborea		1.9								
Morus alba			0.2		1.1					
Prunus rufa					1.1	0.5		1.5		
Alangium sp						0.5				
Lyonia ovalifolia									0.7	
DECIDUOUS BROAD-LEAVED SHRUB										
Indigofera dosua	50.0	17.0		4.1	2.2		1.8		0.8	
Viburnum mullaha	11.1				1.1		4.8			
Zanthoxylum armatum	5.6	3.8	0.2		2.2			11.8		
Phylanthus urinaria			20.5			3.4				
Swida oblonga			5.5	1.4		0.5	8.6			
Benthamidia capitata			3.4	2.7		19.1	2.5			
Randia tetrasperma			0.8		13.0	0.5				
Viburnum sp			0.5							
Lespedeza sp			0.5		1.1	2.5	1.9			
Zizyphus incurva			0.2		6.5			1.5		
Coriaria nepalensis				5.4		0.5				
Chaenomeles sp				2.7						
Elaeagnus parvifolia				1.4	1.1	0.5		1.5		
Erythrina arborescens				1.4				1.5		
Lonicera obovata					10.9					
Desmodium elegans					1.1	1.0				
Toricellia tiliifolia					1.1					
Viburnum foetidum						5.4				
Rosa sericea						0.5	1.5			
Colquhounia coccinea							1.5			
Evergreen needle leaved conifer										
Pinus roxburghii			0.3	4.1					2.8	
Pinus wallichiana						0.5			0.7	
TOTAL	100	100	100	100	100	100	100	100	100	100

Field Crops

The Effect of Height Reducing Genes (Rht_1 & Rht_8) on Establishment of Wheat

Wangda Dukpa[1]

ABSTRACTS

The study was conducted to determine the effect of height reducing genes Rht_1 and Rht_8 and sowing depth on seedling establishment of wheat. Control, Rht_1 and Rht_8 were evaluated at 0 cm, 2 cm, 4 cm and 6 cm sowing depths in a complete randomised design with three replications. Interactions between varieties and sowing depth had no significant effect on all the parameters except on percentage seedling emergence. Increasing sowing depth significantly increased the days to first seedling emergence, duration of seedling emergence and seedling height. There was no significant difference between varieties in the days to first seedling emergence, duration of emergence, percentage emergence and root length. Coleoptile length above the soil, root length and shoot dry matter decreased significantly with increasing sowing depth. Coleoptile length and shoot dry matter of control were significantly longer and higher than Rht_1 and Rht_8 respectively.

KEYWORDS:

Height reducing genes, days to emergence, duration of emergence, percentage emergence, coleoptile length, seedling height, root length, shoot dry matter, *Triticum aestivum* L.

INTRODUCTION

Plants with early vigour shade the soil more quickly decreasing evaporation and improving the ability of the plant to compete with weeds, increase water use and nitrogen uptake (Rebetzke *et al*., 2000). Dwarfing gene Rht_1 (Rht-B1b) reduces height and significantly increases yield (Pereira *et al*., 2002) but this gene produce short and

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weak coleoptiles, which are essential for successful emergence and early plant vigour (Rebetzke *et al*., 2000). Genes that reduce height without compromising seedling vigour or coleoptile length have great potential for wheat improvement (Ellis *et al*., 2004).

The dwarfing gene Rht_8 does not reduce the length of coleoptile (Rebetzke *et al*., 2000), which therefore does not affect early growth. Sowing depth depends on the seed size and in general the smaller seeds are sown at a shallower depth. However, seeds are sown at various depths depending on the type of equipment used and cultural practices but with an ultimate aim to quickly establish a vigorous crop. Seeding depth could be an important factor in establishing a crop. Seeding too deep results delayed emergence and weak seedlings while seeding too shallow may place the seeds in the soil that is very dry and result in poor germination (Chapman, 2001). As sowing depth increases emergence is less complete and duration of emergence (from first to last plants emerged) also increases with sowing depth (Moes, n.d).

Despite the importance of early crop vigour for higher yields, little attempt has been made on the effect of height reducing genes and sowing depth to early crop establishment. This study attempts to determine the effect of sowing depths and dwarfing genes on the early growth characteristics of wheat.

MATERIALS AND METHODS

The experiment was conducted in the glasshouse from 4 February to 11 March, 2005 in the University of Reading. Three wheat (*Triticum aestivum* L.) varieties; two dwarfing genotypes with height reducing genes (Rht_1 and Rht_8) and a control (landrace) were evaluated at sowing depths of 0 cm, 2 cm, 4 cm, and 6 cm respectively on the compost soil filled in a 10 cm x 10 cm plastic pots. Each treatment was replicated three times in a complete randomised design since all pots were assumed uniform and no other factors vary in the experimental area. Ten seeds of each variety were placed at equidistant for each pot. Each pot was considered as a replicate. The pots were irrigated weekly and the soil moisture was maintained at field capacity.

The experiment was monitored daily from the day of sowing and recorded seedling emergence till the experiment was terminated. The days to first seedling emergence and the duration of emergence (from first to last seedlings emerged) were recorded. The mean percentage of seedling emergence was calculated at the end of the experiment. The length of coleoptiles above the soil for all seedlings of each pot was measured after reaching the maximum length as indicated by the emergence of the primary leaf from the coleoptile tip. The stems were cut at soil level, placed in a paper envelope separately for each pot, labelled and dried in the oven at 45^0C for 66 hours and the weight of dry matter was recorded. Root lengths for all seedlings of each pot were measured and the average for each pot was calculated and recorded.

The data was processed in Excel and analyses of variance for all parameters and interactions between variety and sowing depths were performed using GenStat (7^{th} edition).

RESULTS AND DISSCUSSION

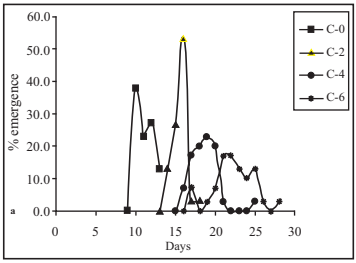
Days to first seedling emergence

There was no significant (P=0.251) difference in the days to first seedling emergence between varieties. Days to first seedling emergence increased significantly ($P < 0.001$) with increasing sowing depth in all the varieties (Figure 1; a, b, c). There was no significant (P=0.799) effect on the days to first seedling emergence due to the interactions between varieties and sowing depths (Table 1).

Table 1. Effects of varieties and sowing depths on days to first seedling emergence (DFE), duration of emergence (DE), % Emergence (% EM), Coleoptile length (CL), Plant height (PH), Root length (RL) and weight of shoot dry matter (DM).

Treatments	DFE (Days)	DE (days)	% EM	CL (mm)	PL (cm)	RL (cm)	DM (gm)
Control							
Depth (cm)							
0	9.00	3.67	100	13.23	8.40	18.67	0.23
2	13.00	4.00	100	5.13	9.20	17.13	0.20
4	15.67	4.67	93	2.07	10.13	17.00	0.17
6	19.67	7.67	93	0.87	9.67	15.67	0.12
Rht_1							
0	9.00	4.67	90	11.27	8.57	19.87	0.20
2	14.00	4.00	100	4.03	8.90	17.60	0.17
4	17.00	4.67	83	0.87	10.30	16.40	0.14
6	19.33	9.00	93	0.43	9.13	15.97	0.11
Rht_8							
0	9.00	4.33	83	10.97	7.34	19.07	0.17
2	14.00	2.67	97	3.87	8.30	17.30	0.18
4	17.00	6.00	100	1.03	9.10	16.73	0.15
6	20.33	7.67	90	0.73	8.20	15.40	0.10
S.E.Ds for comparisons between:							
Sowing Depth means	0.515	0.689	3.040	0.389	0.216	0.547	0.010
Variety means	0.446	0.597	2.640	0.337	0.187	0.473	0.009

Duration of seedling emergence



Duration of seedling emergence significantly ($P<0.001$) increased with increasing sowing depth in control. There was no clear trend in Rht_1 and Rht_8 but there was a significant difference in duration of seedling emergence between

sowing depths (Table 1). In Rht_1 and Rht_8 shortest duration of seedling emergence occurred at the sowing depth of 2 cm (Fig. 1, a, b, c). There was no significant (P=0.609) difference in duration of emergence between the varieties. Interactions between varieties and sowing depth had no significant (P=0.591) effect on duration of seedling emergence.

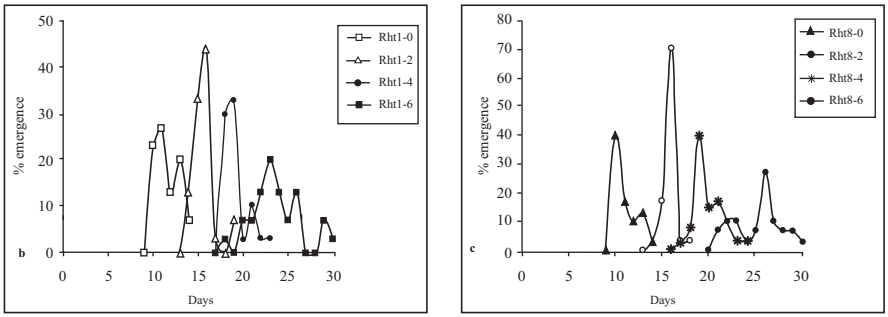


Fig. 1 (a, b, c). Days to first seedling emergence, duration of emergence and percentage emergence of control, Rht_1 and Rht_8 wheat seeds.

Percentage seedling emergence

The mean percentage seedling emergence for control was 96.67%, Rht_1 (91.67%) and Rht_8 (92.50%) respectively. There was some evidence in control that emergence percentage decreased with increased sowing depths but no trend was observed in Rht_1 and Rht_8 (Table 1). There was no significant difference of percentage seedling emergence between sowing depths (P=0.066) and between varieties (P=0.149). However, interactions between varieties and sowing depths had significant (P=0.030) effect on percentage seedling emergence.

Coleoptile length

Coleoptile lengths above the soil in all the varieties decreased significantly (P<0.001) with increasing sowing depths except in RHt_8 where there was no significant difference between depths of 4 cm and 6 cm. The coleoptile lengths of control were significantly (P=0.002) longer than the Rht_1 and Rht_8 (Table 1). There was no significant difference in coleoptile lengths between Rht_1 and Rht_8 at all sowing

depths. Interactions between varieties and sowing depths had no significant (P=0.504) effect on coleoptile length.

Plant height

In all the varieties plant heights increased with increasing sowing depths, shortest at 0 cm and tallest at 4 cm but significantly (P<0.001) reduced height at 6 cm. Plant heights were significantly different at different sowing depths. The plant heights of control and Rht_1 were significantly (P<0.001) taller than Rht_8 at all sowing depths but there was no significant difference between control and Rht_1 (Table 1). Interactions between varieties and sowing depths had no significant (P=0.704) effect on plant height.

Root length

Root lengths decreased significantly (P<0.001) with increasing sowing depths in all the three varieties (Table 1). However, there was no significant (P=0.716) difference in root lengths between varieties. Interactions between varieties and sowing depth had no significant (P=0.913) effect on root lengths.

Shoot dry matter

Shoot dry matter of all varieties decreased significantly (P<0.001) with increasing sowing depths except in Rht_8 where there was no significant difference between depths 0 cm and 2 cm. Dry matter of control was significantly (P=0.005) higher than Rht_1 at all sowing depths except at 6 cm depth and significantly higher than Rht_8 at 0 cm depth (Table 1). Interactions between varieties and sowing depths had no significant (P=0.406) effect on shoot dry matter accumulation.

The results of this experiment show the effect of height reducing genes and the sowing depths on the establishment of wheat seedlings. Two genotypes with height reducing genes Rht_1 and Rht_8 were evaluated against the control (landrace). Days to first seedling emergence and duration of emergence decreased progressively with increasing sowing depth, which conforms to the earlier studies (Chapman, 2001;

Moes, n.d). As sowing depth increases temperature gets cooler thus delay germination and emergence. Even if the seeds at different depths germinate at the same time, seedlings from the deeper depths will take longer time to emerge as the seedlings grow through larger amount of soil. The evidence therefore indicates that uniformity or spontaneity of seedling emergence decreases with increase in sowing depth. The evidence also shows that control and genotype with height reducing genes take almost same days to seedling emergence and duration of emergence.

The earlier studies show that seedling emergence is incomplete with increase in sowing depth (Moes, n.d). However, in this study, there was no significant difference in percentage seedling emergence at different sowing depths as well as between the varieties. The difference in percentage seedling emergence could be more pronounced if the differences of sowing depths are further increased. However, sowing seeds at the surface under field condition may be not practical as it would be difficult to maintain soil moisture as in the glasshouse. Therefore, germination in many species is inhibited when seeds are on the soil surface (Bewley and Black, 1994).

The coleoptile length above the soil decreased with increasing sowing depth and the coleoptile length of control were significantly longer at all depths than Rht_1 and Rht_8. It is reported that height reducing genes Rht_1 reduces coleoptile length but Rht_8 does not reduce coleoptile length (Ellis *et al*., 2004; Rebetzke *et al*., 2000). Conversely, the evidence shows that height reducing genes Rht_8 also reduces coleoptile length. The difference could be because the past studies measured total coleoptile length while this study measured the length above the soil. The coleoptile plays an important role in seedling emergence as it encases the first leaf and pushes through the soil to the surface. The control with long coleoptile could be sown at more variable or greater depths than Rht_1 and Rht_8.

Seedling heights of all the varieties increased with increasing sowing depth from 0 cm to 4 cm but reduced significantly at 6 cm which could be attributed due to delayed emergence. Control seedlings were significantly taller than Rht_8 but not significant from Rht_1. The

evidence indicates that Rht_8 reduces seedling height while Rht_1 does not reduce seedling height but effects later in development of the plant as previously reported (Ellis *et al*., 2004). These genes reduce plant height by decreasing the sensitivity of reproductive and somatic tissues to endogenous gibberellins (Sial *et al*., 2002).

Root length decreased with increasing sowing depth but there was no significant difference between varieties. It is possible that the seeds at a greater depth utilise more food from the food reserves of the seed for shoot development as seeds at a greater depths require additional horsepower to pull the drill and reach the surface (Chapman, 2001). The evidence that increase in seedling height with increase in sowing depth also supports that more food from the seed is utilised for shoot development.

Dry matter decreased significantly with increasing sowing depth and dry matter of control was significantly higher than Rht_1 and Rht_8 but there was no difference between Rht_1 and Rht_8. Seeds at the shallower depth emerge early, expose to daylight and photosynthesis occur thereby increasing water use and nutrient uptake resulting higher dry matter accumulation (Rebetzke *et al*., 2000) as compared to seeds at a greater depths. Seedlings at 6 cm depth had yellow bands and were relatively weak as in the past report (Chapman, 2001).

CONCLUSIONS

This study was able to determine the effect of height reducing genes and sowing depths on shoot dry matter, which was not quantified in the previous studies. Seeds sown at a shallower depth germinate, emerge and establishes earlier than seeds sown at greater depths. The height reducing gene Rht_8 reduces seedling height but Rht_1 does not reduce seedling height thus Rht_1 favouring early crop establishment. The control with long coleoptile length above the soil can be sown at variable or greater depths than height reducing genotypes (Rht_1 and Rht_8).

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Growing Rice in Bumthang: A Dream Realized by the Farmers

Wangda Dukpa[1], Deki Pem[2] & Gyem Lhamo[3]

ABSTRACT

Rice (Oryza sativa) research in Bumthang started in 1998 with the objectives to; identify suitable varieties, reclaim marshy areas, introduce rice cultivation technologies, diversify the farming systems and enhance rice self-sufficiency. Twenty seven varieties have been evaluated of which 'Jakar Ray-Naap' has been identified as the most suitable variety under Bumthang condition. Nursery can be raised successfully using semi dry-bed method. Wet-bed method of raising nursery is seen as an alternative method. Nursery sowing dates and transplantation dates has been identified. Number of farmers taking up rice cultivation and area under rice cultivation has been increasing steadily and in 2006, 61 farmers are cultivating rice in 41.52 acres. Jakar Ray-Naap takes 230-235 days from seed to seed. The average yield of Jakar Ray-Naap is 2406 Kg/acre. Considering 70% total milling recovery, Nu.40/Kg of milled rice, a farmer can generate a total of Nu 67,368 from an acre of rice field. Low temperature affects crop growth and reduces tillering, in worst cases up to 6 tillers/hill. Echinochloa crus-galli, Digitaria ciliaris, Schoenoplectus juncoides, Alopecurus aequalis, Persicaria hydropiper and Drymaria cordata are the dominant weeds. This paper discusses the nursery raising methods, days to maturity, yield, effects of low temperature, rice cultivation trend and constraints.

KEYWORDS:

Jakar Ray-Naap, water temperature, yield, tillers, % sterility, nursery methods, days to maturity, weeds, total milling recovery, outreach programme.

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INTRODUCTION

Farmers in Bumthang cultivate buckwheat, barley, wheat, maize, mustard, legumes (*Phaseolus* spp.), potato and vegetables. Buckwheat, barley and wheat are the principal cereals while potato is their main cash crop. Potato-buckwheat, potato-barley and potato-wheat are the dominant cropping patterns. Although chemical fertilizers and pesticides are heavily used for potato cultivation, cereals are generally cultivated with minimal chemical inputs. Soil fertility is primarily maintained through application of animal manures. Rice cannot be grown in many areas either due to the cold climates, lack of irrigation or unsuitable topography. It was believed that rice cultivation is not possible in Bumthang due to its cold climate (MoA, 2002), minimum temperature required for rice growth is 7^0C (Yoshida, 1977 as cited in Norman et al., 1995).

Crop cultivation in Bumthang is limited by low temperatures in the winter. On an average, there are only 274 days of vegetation period (Dorji, 1999) in Batpalathang (2650 masl). Due to the low temperature, only winter barley and winter wheat _
which require vernalization can be grown in winter. Coldest month is January with an average temperature of 4.2^0C and hottest month is July with an average temperature of 18.1^0C (Fig.1). The lowest temperature recorded since 1989 till 2002 in Chamkhar (2600 masl) is -14.5^0C and maximum temperature is 28^0C (MoA, n.d). Frost occurs as late as May 7 and as early as October 26 while snowfall can occur as late as April 20 (Personal diary). Bumthang receives a mono-modal pattern of rainfall with an annual rainfall of 727.61 mm, maximum rainfall occurring in July and August (Fig. 1).

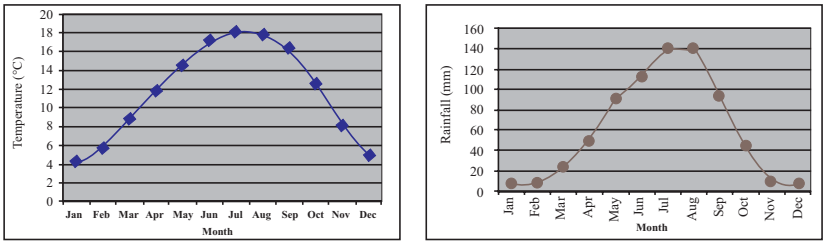


Figure 1. Average annual temperature (^{0}C) annual rainfall (mm) of Chamkhar (average of 12 years)

Results of the soil analysis from six different rice fields show that the soils are sandy type with moderate to shallow depth. Soil pH ranges from 5.07-6.29, low to preferred range for most crops. However, soil acidity is not a problem for rice cultivation as the pH would increase with flooding through dilution effect (NSSC, 2004). There is a wide variation in NPK content and the organic matter varies between 2.75%-11.52%.

It is believed that rice cultivation in Bumthang was tried in Garpang during the reign of second King, His Majesty Jigme Wangchuck but the crop could not reach maturity probably due to the lack of suitable variety. Since then, rice cultivation have never been tried and Bumthang remained a non rice-growing district despite many agricultural lands located on flat to gentle slope and abundance of water. There are also marshy areas remaining as wastelands which can be reclaimed and converted under paddy cultivation. Unlike in many other parts of the country, land topography favour mechanization which could help address the growing labour shortage problem. Farmers in Bumthang cultivate potato, sell their produce and buy rice with that money which clearly indicates their preference for rice, a change in food habit through time.

Therefore, rice research in Bumthang started in 1998 (RNR RC Jakar, 1999) with the objectives to; a) identify suitable varieties for Bumthang condition, b) reclaim marshy areas that are remaining as wastelands and convert under rice cultivation, c) generate rice cultivation technologies, d) diversify the farming systems and e) enhance rice self-sufficiency.

MATERIALS AND METHODS

Germplasm evaluation

High altitude rice research in Bumthang started in 1998 in Gongreythang (2600 masl). Later on, trials were also carried out in Chamkhar (2600 masl) and Batpala (2650 masl). Since 1998 till date, the centre has evaluated 27 varieties, 5 indigenous varieties and 22 exotic varieties. Of the 27 varieties, Paro-China that was introduced from China has been identified as the most suitable variety. It was released as 'Jakar Ray-Naap' by the 11th meeting of the Variety Release Committee. Further, the centre is planning to collect and evaluate more high altitude indigenous as well as exotic varieties.

Nursery

During the initial years, research was concentrated on identifying suitable nursery raising methods and on identifying suitable sowing date. Research focus was on developing technologies that are simple and cheap that can be adopted by the farmers. Farmers can raise nursery using semi dry-bed and wet-bed methods both under polytunnel. Nursery can also be raised at low altitude areas such as Langthel in Trongsa (1200 masl) under normal condition and transported to Bumthang. Details of nursery raising methods and management practices are given in 'the guidelines for rice cultivation in Bumthang District' (Dukpa & Wangdi, 2006).

Nursery using semi dry-bed method should be raised by the first week of February so that seedlings are 60-70 days old and attain 3-5 leaf stage during transplantation. Raising nursery by the first week of March using wet-bed method can produce 32-42 days old and 2-4 leaf stage seedlings. Studies on tray nursery for machine transplantation are being carried out to refine the technology and make it suitable under Bumthang condition.

Transplantation and weeding

Transplantation dates were studied at the research stations and also through multi-location trials at different altitude range.

Transplantation should be carried out by 3rd -4th week of April so that the crops reach maturity and harvested before the occurrence of frost. For manual weeding, seedlings can be transplanted at 20cm x 20cm spacing while for rotary weeding, seedlings should be transplanted at 25cm x 25cm spacing for convenience in weeding. One-two seedlings are transplanted per hill and 2-3 hand or rotary weeding is carried out at about 30, 60 and 90 days after transplantation.

Irrigation

Water level is maintained at 2-3 cm during transplantation and until the seedlings recover. After the seedlings have fully recovered, water level is gradually increased and maintained at 5-8 cm. In order to avoid the low temperature effect, fields are irrigated in such a way that the water flows from one terrace to the other and the water inlet and outlet of the terrace are at two opposite ends of the terrace. To maintain the water temperature at night, fields are irrigated in the morning (9 am) and cut off the water supply in the evening (4 pm). Irrigation is stopped and the fields are drained out 10-14 days prior to harvest to enhance ripening.

Soil fertility management

In line with the principle of producing and exporting Bumthang rice as organic produce or as the product of natural farming, rice is cultivated using locally available Farm Yard Manure (FYM), without chemical fertilizers and pesticides. It is practically difficult to level the terraces uniformly for the first year resulting uneven distribution of water and manure. Therefore, to avoid too much manure in one side of the fields, which promote too much vegetative growth resulting high per cent sterility, farmers are recommended not to apply FYM for the first year. In general, as per the recommendation from the National Soil Service Centre, 4000 Kg of FYM/acre is recommended (NSSC, 2004).

Harvesting

In a population, there are some plants that mature earlier than others. Panicles of the early maturing plants were selected, bulked and multiplied the seeds. This technique help reduce the number of days to

maturity. The crop should be harvested by 2nd-3rd week of October (when 85% of the upper portion of panicles turn straw coloured) to avoid damage from early frost. Seed selection and maintenance of quality seeds are important to obtain and maintain a good crop yield.

Yield assessment

Grain yields were assessed using the conventional method of crop cuts (6 m^2). Three random samples were taken from each field. Yields were also assessed using yield component analysis. Crop was harvested from 1 m^2, counted number of panicles, assessed grain yield and other yield components (Yield (t/ha) = 1000 grain weight (g) x % filled spikelet x spikelet number/m^2 x 10^{-5}) from all the sites and the average yield (Kg/acre) was calculated.

Outreach programme

Rice cultivation in Bumthang district (Tang and Chokor blocks) up-scaled since 2004 with the instructions from the Ministry of Agriculture in collaboration with the District Agriculture Sector. Since rice cultivation is a new activity in Bumthang, incentives were provided to the farmers by the Ministry of Agriculture to encourage rice cultivation. The Central Machinery Unit under the Department of Agriculture (DoA) provided earth moving machineries to the farmers in reclaiming the marshy areas and making drainage. The Rural Enterprise Development Project (REDP) and East Central Region Area Development Project (ECRADP) provided irrigation pipes to the farmers.

RNR RC-Jakar provided seedlings free of cost to all the farmers who took up rice cultivation for the first year. In the second year, farmers were taught how to raise their own nursery through workshops, seminars and trainings. From third year onwards, the centre provided technical assistance through regular monitoring of the fields. RNRRC-Jakar also assisted the farmers in laying out terraces. Besides the technical assistance and training, farmers carried out activities such as field preparation, weeding, irrigation and harvesting by themselves.

RESULTS AND DISCUSSION

Nursery raising methods

Raising nursery by the first week of February using semi dry-bed method under polytunnel can produce seedlings of 60-70 days old and that are 3-5 leaf stage, physiologically attaining optimum height and stage for transplantation. This method is widely adopted by the farmers since the technology is simple and cost-effective. Studies at the research station for the last 3 years also show that raising nursery by the first week of March using wet-bed method under polytunnel can produce 32-42 days old and 2-4 leaf stage seedlings. Wet-bed method can produce seedlings at a much shorter duration than the semi dry-bed method. Wet bed method requires pre-germination of seeds unlike the semi dry-bed method which enhance seedling growth. Further, continuous standing water in the wet-bed method could maintain particularly the night temperatures warm. Unlike in semi dry-bed method, continuous standing water in the wet-bed method reduces the moisture stress. However, unlike semi dry-bed method, wet-bed method requires well-leveled bed for even distribution of water for uniform seedling growth. Wet-bed method is seen as an option for the farmers. Besides the nursery raising methods, growth of seedlings also depend on the seed rate, nutrient status of the soil and the management practices.

Yield difference between different ages of two varieties (Jakar Ray-Naap and Chumro) of seedlings was studied using RCB design. Three months old seedlings raised using semi dry-bed method and one month old seedlings raised using wet-bed method were used for the evaluation. No significant difference in grain yield between different ages of seedlings was observed in Jakar Ray-Naap but there was a significant difference in Chumro (Table 1). The result show that the short duration variety (Jakar Ray-Naap) germinate fast and the seedlings attain the required stage faster than the late maturating variety (Chumro). Therefore, nursery raising dates may vary depending on the durations of the crops.

Grain yield (Jakar Ray-Naap) of the seedlings that were raised in Bumthang and Trongsa was assessed. Seedlings raised in Bumthang

performed better than the seedlings that were raised in Trongsa (Table 2). The evidence show that the seedlings raised in Bumthang were adapted to Bumthang condition while the seedlings that were raised in Trongsa when brought and transplanted in Bumthang did not perform well indicating that the seedlings suffered shock from sudden change in climatic conditions. Therefore, it is not advisable to raise nursery in the warmer areas for cultivation in the higher altitude zones. Further, transportation could incur additional cost.

Table 1. Yield comparison between different ages of two varieties of seedlings

Variety	Yield (Kg/ac)	MC (%)
Jakar Ray-Naap (1 month)	2099.48	19.0
Jakar Ray-Naap (3 months)	2098.54	19.1
Chumro (1 month)	522.93	21.1
Chumro (3 months)	943.03	19.3
LSD (0.05)	290.90	2.3
CV (%)	10.3	6.3

Source: Dukpa, 2004

Table 2. Grain yield (Kg/acre) of nursery raised in Trongsa and Bumthang at different test locations

Variety	Location (Yield Kg/acre)						
	Ken-chosum	Mesi-thang	Pangzhing	Jalkhar 1	Jalkhar 2	Gongrey thang	Batpala
Jakar Ray-Naap-B	1157	190	352	1000	421	801	668
Jakar Ray-Naap-T	797	271	16	635	174	607	405

Note: Jakar Ray-Naap-B=Nursery raised in Bumthang, Jakar Ray-Naap-T=Nursery raised in Trongsa **Source**: RNRRC-Jakar, 2003

Duration of the crop

Jakar Ray-Naap takes 110-115 days to 50% flowering from transplantation and 180-185 days from seed sowing. It takes 160-165 days to mature from transplantation and 230-235 days from seed to seed (Table 3). Rice in Bumthang takes much longer to mature than the rice in warmer areas such as in Gelephu (250 masl). In Gelephu, local popular variety 'mama' takes 166 days and an improved variety 'BR

153' 151 days respectively to mature from seed to seed. Crop maturity vary among different agro-ecological zones (AEZ) due to the variation in weather/climatic condition, warmer the temperature greater the rate of progress towards flowering (Roberts, 1991) and therefore takes shorter days to mature. Results also show that shorter duration has low per cent sterility than the longer duration variety. Longer duration variety taker longer days to flowering and thus flowering can occur during the fall in temperature. Low temperature at flowering inhibits panicle exertion from the flag leaf resulting high sterility (Mackill *et al*., 1996). It is also observed that shade affect crop maturation. Trees or structures that shade the field in the morning hours delays vegetative growth, flowering and maturation resulting high sterility.

Table 3. Agronomic traits of two rice varieties

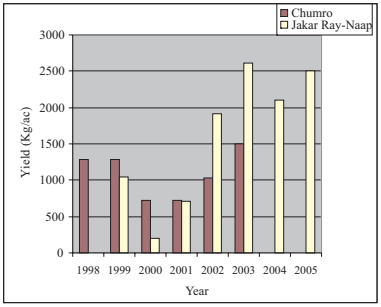
Variety	Days to maturity	Plant height (cm)	No. of tillers/hill	Panicle length (cm)	Total grains/ panicle	% Sterility
Chumro	170-175	95.53	20	20.96	107	30.44
Jakar Ray-Naap	160-165	91.71	25	17.74	111	12.34
LSD 0.05		8.65	2.32	1.40	2.74	4.18
CV (%)		4.2	5.3	3.3	3.2	3.80

Yield Assessment

The result show fluctuation of the grain yields during the initial years and gradually yield stabilized since 2003 (Fig. 2) particularly Jakar Ray-Naap. From 1998 to 2002, research was concentrated on identifying suitable nursery sowing dates, transplantation dates and harvesting dates. Therefore, yield fluctuations during the initial years could be attributed to changes in the planting dates. Both varieties are exotic, Chumro was introduced from Nepal and Jakar Ray-Naap from China respectively. Crops take time to adapt to the new environment, which is why yields were low during the initial years but the yields increased as the crops adapted to the local climatic conditions. The average yield of 2004 was relatively lower than the yield of 2003 and 2005. Low yield in 2004 could be due to the seeds brought from Paro which were not adapted to Bumthang condition. Further, all fields were

new and our observations show that the crops do not perform well in new terraces due to high percolation and uneven distribution of water and nutrients.

Figure 2. Rice grain yield (Kg/ac) in Bumthang from 1998-2005



Uniform crop growth can be obtained by second or third year when the terraces are well-established. The yield of 2004 and 2005 are relatively lower than the yield of 2003. This was because in the past chemical fertilizers were applied while rice cultivation in 2004 and 2005 was without fertilizers.

Grain yields were assessed through conventional method of crop cuts from 6 m^2 and converted to yield/acre (Table 4). Yield components were also assessed using Yoshida's formula to revalidate the crop cut data (Table 5). No substantial difference in yield was observed between yield that was assessed through crop cuts and that evaluated using Yoshida's formula. The evidence, therefore, revalidates the crop cut data. The average yield of Jakar Ray-Naap for the last three years is 2406 Kg/acre, higher than the national average rice yield of 1166 Kg/ac (MoA, 2004). Duration of crop maturity increase with increase in altitude and therefore duration of nutrient uptake increase with increase in altitude. Yield increase with increase in altitude could be attributed to higher nutrient uptake due to longer crop growth duration given other conditions remain favourable for crop cultivation.

Plant density varies from site to site depending on nutrient status of the soil, irrigation source, aspect and altitude. Rice cultivation in Bumthang ranges from 2530-2700 masl. There are on the average 481panicles or productive plants/1 m^2 and 820 panicles or productive plants/1 m^2 in well managed fields.

The average total milling recovery (Total milled rice (%) = weight of

total milled rice/Total weight of rough rice x 100) of Jakar Ray-Naap is 70% and weight of 1000 grains is 21g. Spikelet sterility was assessed taking 10 panicles at random from each of the replicated plots. Spikelet sterility of Jakar Ray-Naap is 19%, significantly ($p<0.01$) lower than Chumro (30%). Low percentage spikelet sterility of Jakar Ray-Naap indicates that it is more tolerant to low temperature than Chumro.

Table 4. Grain yield of Jakar Ray-Naap (crop cut from 6 m^2) at different locations (2005)

Location	Altitude (masl)	Yield (Kg/ac)	MC (%)
Changwa	2620	2227.20	14.2
Changwa	2620	1821.15	13.7
Changwa	2660	2741.17	19.2
Gongkhar	2570	2451.13	20.7
Jalkhar	2530	2835.60	19.7
Jalkhar	2530	3155.31	16.0
Dekiling	2600	1687.60	19.9
Dekiling	2600	2305.44	19.6
Wangdicholing	2600	1687.60	19.9
Wangdicholing	2600	3079.77	19.2
Wangdicholing	2600	2231.25	16.7
Dorjibee	2640	2186.73	17.5
Pralang	2660	3669.28	17.3
Pralang	2660	3819.02	14.5
Pangzhing	2700	3480.42	14.8
Kunzangdra	2700	1831.94	18.3
Kunzangdra	2700	2528.03	18.8
Bepzur	2700	2770.85	13.9
Bepzur	2700	3147.2	18.4
Bepzur	2700	2784.3	16.9
Jambaylhakhang	2620	2902.71	11.6
Jambaylhakhang	2620	2519.26	10.6
Changwa	2660	2741.17	19.2
Changwa	2655	2530.72	16.5
Kenchosum	2640	2186.73	17.5
Tsakorthang	2600	2046.43	19.4
Tsakorthang	2600	1993.82	21.3
Bepzur	2700	2943.52	16.0
Average		**2582.34**	**17.2**

Table 5. Yield components and grain yield of Jakar Ray-Naap using Yoshida's method from different locations in Bumthang (2005)

Location	No. of panicles ($1m^2$)	No. of grains ($1\ m^2$)	No. of unfilled grains ($1\ m^2$)	Total no. of spikelets ($1\ m^2$)	% filled grains	1000 grain weight (gm)	Yield (Kg/acre)
Nimalung	746	36340	15032	51372	74.84	22.72	3310
Pralang	720	56608	25488	82096	68.95	21.16	4529
Bepzur (Rinchen)	270	8436	5988	14424	45	18.51	728
Bepzur (Petheymo)	108	1812	6000	7812	23.20	17.72	130
Bepzur (group)	398.6	24624	8533	33157	74	21.87	2197
Pangzhing	520	47820	7964	55784	85.72	23.04	4456
Jalikhar	820	37260	12006	49266	76.9	23.57	3545
Changwa	450	25708	8880	34588	74.02	22.7	2420
Tsakorthang (Machine)	460	12644	22916	35560	35.56	17.76	907
Tsakorthang (manual)	520	27916	9448	37364	74.71	20.16	2274
Kenchosum	260	20400	2872	23272	87.66	23.05	1902
Average	**479**	**27233**	**11375**	**38609**	**65.5**	**21.1**	**2400**

Water temperature

Water temperature was monitored from transplantation to harvest in 10 sites (Tang and Chokor) during the day to study the effect of water temperature on crop production. The average temperature of Chamkhar river (14^0C) was found to be lower than the streams (18.2^0C), which are the sources of water for irrigation by about 3-4^0C. Temperature of the sources of irrigation was lower than the air temperature (19.1^0C) by 0.9^0C. Temperature of the sources of irrigation varies depending on the location and vegetation cover. Lowest temperature at the source recorded is 14^0C. As the water moves through the small channels to the field, temperature increases by 2.3^0C when the water reaches and enters the first terrace (20.5^0C). Water spreads in the field, temperature increases and within the first terrace, a temperature difference of 2.3^0C was observed. No difference in temperature was observed between the second and other terraces. Low temperature was found to affect the crop production. Crop performance particularly at the first terrace where the cold water first enters the field is affected more than other terraces. Low temperature

delays crop growth, crops are weak, pale yellow in colour and reduce tillering in worst cases by 6 tillers/hill. It is, therefore, recommended to make a water collecting pond before entering the field to raise the water temperature and thus to avoid cold temperature effect particularly in the first terrace.

Status of rice cultivation

In the beginning, farmers had some reservation to take up rice cultivation on large scale which is not surprising considering rice cultivation, a new culture which is alien to Bumthang farmers. However, farmers were convinced that rice can be grown successfully in Bumthang after attending a field day in Kenchosum (plot size of 248 m^2) in 2003. Since 2004, through the outreach programme, rice cultivation in Bumthang has been increasing steadily (Fig. 3) and this trend will continue for some more years. About 27% of the total rice area is a reclaimed marshy land.

The number of farmers taking up rice cultivation and the area under rice itself is a clear indication that the farmers are satisfied with the return they earn from the crop. Farmer from Jambay Lhakhang, Ms.Yangdon said "I feel fresh and gain energy to work when I visit my rice field fully exhausted from other field works". Considering the average yield of 2406 Kg/ac, an average total milling recovery of 70% and a farm gate price of Nu.40/Kg for milled rice, a farmer can generate a total of Nu.67,368 from an acre of rice field. A detail economic study on rice cultivation in Bumthang is under way. Farmers take up rice cultivation because they need less time to guard the field (from milky stage till harvest) against wild animals unlike in potato where they need to guard the field from day 1 till harvest. Further, rice is more stable from food security perspectives, they produce and consume while income from potato is dictated by market forces.

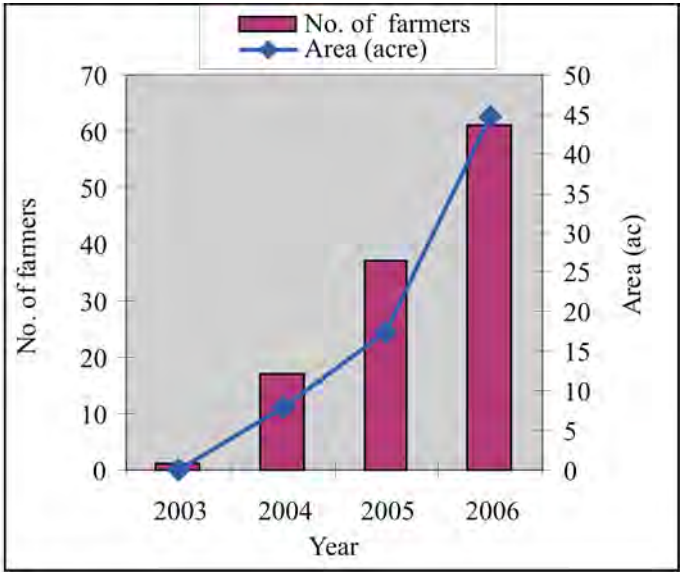


Figure 3. Rice cultivation trend in Bumthang from 2003-2005

Constraints

Variety options

At present, there is only one variety, Jakar Ray-Naap suitable for cultivation under Bumthang condition. Therefore, farmers have limited choice of rice varieties. Jakar Ray-Naap is susceptible to Blast, a disease caused by the fungus *Pyricularia grisea*. Although Jakar Ray-Naap is susceptible to blast, no blast incidence was observed till 2003 under Bumthang condition. Therefore, blast in 2004 could have been caused by the inoculum, which might have been introduced through infected seeds that were brought from Paro in 2004. Incidence of sheath blight (2.5%), a disease caused by the fungus *Rhizoctonia solani* was also recorded. Due to the limited choice of variety, there is a danger of crop failure if blast epidemic occur. Therefore, there is a need to identify and introduce early maturing, high yielding and blast resistant varieties.

Physiological/nutrient disorders

Yellowing of older leaves occur at maximum tillering stage. Yellowing could not be due to low temperature since yellowing does not occur during the early tillering stage when the temperature is relatively lower than during the maximum tillering stage. The competition for the available nutrients and other resources is likely to increase as the crop grows, competition would have reached maximum during the maximum tillering stage causing yellowing of leaves. Highest tiller mortality due to competition for nutrients is also reported to occur before anthesis on barley (Garcia del Moral, 1995). Some incidence of whole rice plants turning yellow and dying of whole hill in sporadic locations especially in the terrace borders was observed. Studies on the cause of the incidence are being carried out in collaboration with NSSC and NPPC, Simtokha.

Weeds

Echinochloa crus-galli and *Digitaria ciliaris* are the dominant weeds in nursery (semi dry-bed method) while *Schoenoplectus juncoides*, *Alopecurus aequalis*, *Echinochloa crus-galli*, *Persicaria hydropiper* and *Drymaria cordata* (Parker, 1992) occur in the transplanted field. The very noxious wetland weed *Potamogeton distinctus* is not recorded till date. However, there is a risk of introducing this weed from other Districts and thus, there is a need to take necessary precautions. Besides weeds, there are occasional damages by rodents and birds.

CONCLUSIONS

Farmers in Bumthang could not grow rice in the past due to the lack of suitable technologies. The high altitude rice research in Bumthang identified suitable variety and generated rice cultivation technologies that are now widely adopted by the farmers. Rice cultivation technology is now successfully introduced in Bumthang which is a significant and historical research achievement. It is imperative for research to focus on screening and developing more varieties to diversify germplasm, reduce the risk of crop losses due to the pests and

diseases and to offer more options to the farmers. Rice cultivation can also diversify the potato-based farming systems. Introduction of rice cultivation technologies in Bumthang can enhance rice self-sufficiency, food security, address balanced development and contribute to the achievement of our national development philosophy 'Gross National Happiness'.

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Indigenous millet nursery raising in tseri: conservation concerns and research options

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ABSTRACT

Majority of farmers of Bumdelling Block are dependent on finger millet for their food security. These farmers have indigenously innovated and adapted millet nursery raising technique in which they use small tseri and pangshing registered under their ownership. The key features of the farmer's practices are the use of tseri land with a fallow period of five to six years and controlled burning. The Bumdelling Park Management has found that farmer's nursery raising practice is detrimental to bio-diversity and has implications on conservation. RNR RC Wengkhar, studied the farmer's nursery raising practices and attempted to explore alternative options of raising millet nursery that are acceptable to farmers, ecologically friendly and pro conservation.

KEYWORDS:

Controlled burning, indigenous innovation, food security, threat to conservation, alternative nursery raising options

INTRODUCTION

Bumdelling block falls within the protected area of the Bumdelling Wildlife Sanctuary. It is the winter habitat for the black necked cranes (*Grus nigricollis*). Agriculture is the main stay of the people. Rice and finger millet (*Eleusine corcana*) are their principle crops. Amongst the cereals, finger millet is the most prominent crop covering 275 acres

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followed by rice with a total cultivated area of 207 acres (MoA, 2000). Majority of the farmers depend on dryland for their livelihood. With the rapid rise in the frequency of seasonal monsoon floods, the existing wetland is getting progressively reduced. In 2004 alone, the monsoon flood washed away 19 acres of wetland (MoA, 2004) making the farmers more dependent on their dryland. The Bumdelling Park Management has found that farmer's age old practice of raising millet in a controlled burning system is a threat to conservation. The Park Management therefore seeks to identify suitable millet nursery raising options that is more benign to biodiversity and less detrimental to conservation. The nursery raising practices according to the farmers are their indigenous innovation and possesses many additional merits. The Renewable Natural Resources Research Centre (RNR RC) Wengkhar, conducted a study to understand the farmer's nursery raising techniques and attempted to identify alternative options of raising millet nursery that are acceptable to farmers, ecologically friendly and pro conservation.

MATERIALS AND METHODS

The first step was to understand the farmer's nursery raising practices and its implications from the perspective of the farmer's and the officials of the Bumdelling Wildlife Sanctuary. This was done by making reconnaissance visits to the block and field discussion. The first visit was made in the second fortnight of January 2005 and preliminary discussions were held with the Park Officials who outlined that the existing farmer's practice of burning was antagonistic and a threat to conservation. The second visit was made in March coinciding with the farmer's field preparation time. During both the visits informal discussions were held with farmers, extension staffs and block officials on various aspects of the farmer's nursery raising system. These visits helped us to understand in detail the farmer's nursery raising practices.

Farmer's Millet Nursery Raising Practices in Bumdelling Block

Farmers raise millet nursery in two ways.

i. Nursery raising on a small *tseri* land through controlled burning

This practice of raising nursery in the *tseri* is by far the most predominant practice**.** *Tseri* is a local term which is synonymously used for shifting cultivation. According to the Survey of Bhutan, a *tseri* land refers to a dryland generally un-terraced and steep, cultivated once every four to six years. *Tseri* is legally owned and registered in their *Thram* (Land Registration Record). In Bumdelling, farmers establish their nursery in these lands which are cultivated every four to six years. The land is intentionally kept fallow for at least for four to six years to maintain soil fertility. The bushes and shrubs are allowed to grow and these are cleared and burnt. Farmers, however, seek prior permission from ***gup*** (Head of a Block) and park officials to slash the bushes. The small trees and bushes are cut down and burnt during the dry season starting from February to March. After burning soil is turned over to incorporate the ashes and then millet seeds are broadcasted. Most farmers seed their nursery in May. The seedlings are almost ready in 30 to 40 days and the crop is transplanted in June.

ii. Nursery raising on *Pangzshing*

The survey of Bhutan defines *Pangzshing* as dryland which are farmed every two to three years. In this practices, fresh uncultivated dryland kept fallow for two to three years is used. The growth of bushes is not as profuse as in *tseri* and minimum slashing is required. Farmer's dig the fallow land, scrap and collect the plant debris and pieces of woods along with soils attached to the debris, and heap them. Once the debris is dried they burn in the field. The soils collected in the heaps are also burnt. Then the soil from the heap is mixed with un-burnt soil in the field. The millet seeds are then broadcasted. Farmers find that nursery raised in this method does not produce seedlings as vigorous as in the *tseri* system. This practice requires additional labour and weeding is cumbersome. This practice resembles to the potato cultivation practices followed by farmers in parts of Bumthang District.

It was also observed that the area cleared for nursery is in the ratio of 1:4 *langdo* (a *langdo* of dryland is equivalent to 1/3 of an acre). Seedlings from one *langdo* nursery is good for four *langdos* of transplanted field. At the individual household level the area burnt is

not very large as the average land holdings of individual households are quite small. Bumdelling block has a wet and humid climate with cool broad leaf vegetation. Farmers do not recall incidences of forest fire as a result of fire escape from controlled burning.

Evaluation of Alternative Nursery Raising Option

After understanding farmer's nursery raising practices, the next step was to try and identify potential nursery raising options suitable to farmers and less detrimental to biodiversity. We tried the possibility of producing millet seedlings on nursery beds established on permanently cultivated dryland (*Kamshing*). The main objective was to find out if seedlings could be produced in nursery beds on dryland under Bumdelling conditions. Nursery for one local variety and two improved varieties were established in 10 m^2 plots in the dryland at three different sites. The seeds were sown in lines that were 20 cm apart. Sufficient amount of FYM and chemical fertilizer was applied at the rate of 30:20:10 N:P:K kg ha^{-1}. 15 kg ha^{-1} nitrogen and the entire amount of phosphorous and potassium were applied at the time of sowing while the remaining 15 Kg ha^{-1} nitrogen was top dressed two weeks after seed germination. To compare the quality and quantity of seedlings raised in dryland, nursery was also raised in the *tseri* exactly in the same manner as done by farmers. The local variety used was Ghokhrel and the two improved varieties were Limithang Kongpu 1 and Limithang Kongpu 2. The trial was replicated at three sites (Table 1).

Table 1. Co-operator farmers and trial sites

No	Farmers Name	Trial Site (Village)
1	Mr. Nawang Gyeltshen	Singmar
2	Mr. Tenzin Wangchuk	Yangteng
3	Mr. Tshewag Gyembo	Kamchadung

The seeds were sown in May in all the three sites and transplanted in June at two sites only. In the third site at Kamchadung, the germination of seeds raised in dryland was poor and therefore they could not be transplanted. Days to 50% germination was scored to find out the time

taken for germination. Plant height of the uprooted seedlings was measured by randomly selecting 20 seedlings from different plots. Seedling vigour/health was scored based on farmer's visual observation. The quantity of seedlings was measured by making them into bundles each containing 60 seedlings and counting the number of bundles from each plot. Farmers were asked to uproot the seedlings raised under different methods and they were asked to judge the ease to uproot seedlings. The uprooted seedlings were transplanted in 30 m^2 plots at two sites.

RESULTS AND DISCUSSIONS

According to the farmers their practice of raising nursery through controlled burning is their indigenous innovation and this practice helps them produce most vigorous seedlings without application of any external inputs like chemical fertilizers or manure. This practice is indeed an indigenous innovation for numerous reasons. Firstly, unlike in the olden days they do not slash huge areas of state forest for nursery and cultivation. Secondly, with the government's policy to discourage shifting cultivation in view of its potential impact on environment, farmer's have started practicing on legally owned registered land. Thirdly, the area used for raising nursery is small and are normally adjacent to the main crop and it serves as a buffer zone that helps them protect their main crop. The wild animals do not immediately enter the main field as there will be some crop in the nursery area. It is also evident that whatever adjustments made are truly indigenous innovation of the farmers as research, extension and park management never provided any ideas to them. It cannot be, however, denied that farmer's system do not possess any elements of the shifting cultivation. The maintaining of fallow period for four to six years, field rotation, slashing of shrubs and bushes and subsequent burning confirm to the elements of shifting cultivation. Satapathy *et. al*. (2003), have defined shifting cultivation as an economy that involves rotation of fields, clearing by fire, absence of draught animals and manuring and use of human labour as the main characteristics of shifting cultivation.

From the alternative nursery option tried in dryland, transplantable seedlings could be obtained at least in two sites. The quality and

quantity of seedlings obtained were compared based on different parameters (Table 2 and 3). Farmers in Bumdelling transplant 40 days old seedlings which could also be produced in the nursery beds in dryland. At the two sites the time taken for 50 % germination in dryland and *tseri* were all most the same. In the data in Table 2 and 3 the days for 50% germination are reflected as the same because the scoring was done at the time of visit to the sites by the researchers. If day to day observation could have been taken there surely will be a difference. The average height of the seedlings of local variety Ghokhrel in both sites was 45 cm in dryland as compared to 50 cm in *tseri*. Millet seedlings 25-30 cm tall are acceptable for transplanting. The average seedling height of improved varieties in both sites under dryland was 42 cm as compared to 53 cm in the *tseri*. Seedling vigour/health scored visually and based on the farmer's judgement was better for seedlings raised in *tser*i. The quantity of seedlings produced in *tseri* was higher at the both the sites. Weed pressure was higher in dryland. However as the seeds were sown in line weeding was easier in dryland. Farmers found that uprooting seedlings was easier in *tseri* compared to dryland. The soil in the dryland is relatively compact as a result of continuous cultivation and limited organic matter and therefore uprooting is difficult. The seedlings were uprooted and transplanted in 30 m^2 plots and seedlings from both the methods matured at the same time in both the sites. Yield was not measured, as this was not the main objective. The improved varieties were slightly late and do not seem suitable for Bumdeling condition.

Table 2. Performance of nursery at Singmar village

Parameters	**Dryland Nursery (Alternative Option)**			**Farmers Method (Tseri)**		
	Local variety Ghokhrel	**L/thang Kongpu 1**	**L/thang Kongpu 2**	**Local variety Ghokhrel**	**L/thang Kongpu 1**	**L/thang Kongpu 2**
Date of Nursery sowing	1st May	1st May	1st May	1st May	1st May	1st May
50% Germination (days)	12	12	12	12	12	12
Seedling vigour/health	Medium	Medium	Very Good	Very Good	Medium	Very Good
Seedling height (cm)	50	47	45	45	50	60
Date of transplanting	22nd June	22nd June	22nd June	22nd June	22nd June	22nd June
Quantity of seedlings (bundles) 1 bundle=60 seedlings	10	9	9	15	15	57
Note : Seedling vigour/health score based on a visual observation and farmer's judgement						

Table 3. Performance of nursery at Yangteng village

Parameters	**Dryland Nursery (Alternative Option)**			**Farmers Method (Tseri)**		
	Local variety Ghokhrel	**L/thang Kongpu 1**	**L/thang Kongpu 2**	**Local variety Ghokhrel**	**L/thang Kongpu 1**	**L/thang Kongpu 2**
Date of Nursery sowing	12th May	12th May	12th May	12th May	12th May	12th May
50% Germination (days)	22	22	22	22	22	22
Seedling vigour/health	Medium	Poor	Very Good	Very Good	Medium	Very Good
Seedling height (cm)	40	35	40	55	55	50
Date of transplanting	22nd June	22nd June	22nd June	22nd June	22nd June	22nd June
Quantity of seedlings (bundles) 1 bundle=60 seedlings	15	6	13	15	15	22
Note : Seedling vigour/health score based on a visual observation and farmer's judgement						

The results from the two sites indicate that transplantable seedlings of millet could be produced in nursery beds established on dryland under Bumdelling conditions. In lower altitudes millet nurseries are raised on dryland. However, the main issue here is that farmers are not convinced with the results. This is an indication of the fact that to immediately change their age old system will remain an uphill task. Darlong (2004), has reported that acceptance and utilization of sustainable alternative interventions developed and recommended to the communities practicing shifting cultivation is amazingly low. Farmer's practice of raising nursery in the *tseri* has been their traditional practice, which they have innovated after long experiences. They are convinced by the merits of their method. The advantages of their method are that the soil in *tseri* is very fertile and millet yield is high. Farmers leave behind the extra and small seedlings after uprooting the required seedlings for transplanting which gives them some extra production. More over as the nursery area is adjacent to the main crop and it serves as a buffer zone that helps to protect the main crop. The result also confirms farmer's claims that seedlings produced in the *tseri* are better.

CONCLUSIONS

Although our results indicate that it is possible to produce millet seedlings in the nursery beds in dryland under Bumdelling conditions, farmers should not be immediately interrupted from practicing their age old indigenously innovated method. Immediate action to alter the established system of nursery raising could affect the millet production and have implications on food security. Farmers need to be convinced on the quality of seedlings produced in dryland. Refining the technique and adapting it to their condition is essential. This will require further demonstration, involvement of communities and positive campaigning. The Park Management should try to concretise the potential threats to conservation from the farmer's nursery raising practices. This will help to convince the communities on the ill effects of their practice to biodiversity. This approach perhaps might be more useful in asking the communities to further adjust their nursery raising practice making it pro conservation. Diversifying the millet based system is a long term way forward and RNRRC Wengkhar has initiated work in collaboration with District Extension on improving existing

fruit plants and observation trials on upland rice does not require burning.

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Encouraging farmers to re cultivate fallow wetland - Are technology options enough?

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ABSTRACT

Rice is the most preferred staple but ironically a high percentage of wetlands are being left fallow. Farmers often attribute technical reasons such as farm labour shortage, insufficient water, poor soil fertility, and increasing pests and diseases as the main causes for the increasing percentage of fallow wetland. In order to encourage and rejuvenate farmers to cultivate fallow wetland, a multi dimensional research outreach program was designed and implemented at Wengkhar, under Mongar Block. The outreach program was multi dimensional as it targeted the community, supported farm mechanisation by investing on essential infrastructures, provided basket of technology options and facilitated community participation. The implementation of the outreach program was lead by RNR RC with extension staff, local leaders and farmers as the key partners. The primary objective of this program was to increase the area under rice by bringing the existing fallow wetland under cultivation.

Despite an initial overwhelming response from the farmers, the key objective to rejuvenate farmers to cultivate the wetland being left fallow could not be achieved. It was apparent that there are much deeper issues as to why the wetlands are being left fallow. This paper brings out some learning points for consideration in designing future rice commodity programs.

KEY WORDS:

Multi dimensional research outreach program, fallow wetland, social issues, technology options

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INTRODUCTION

Until 1997, Wengkhar used to be like any remote far flung villages despite its proximity to the burgeoning Mongar town and the national high way. In 1997, government approved the proposal to set up the regional Renewable Natural Resources Research Centre (RNR RC) at Wengkhar. As a result of this decision, the Wengkhar communities first had the privilege of using the approach road which improved their accessibility. As the development of research farm in their vicinity progressed, the community's access to improved technologies such as vegetable seeds and seedling of fruit trees was also enhanced.

However, this was not the case in rice. Despite being central to Bhutanese diet and tradition, it was quite unpleasant to see large areas of wetland adjacent to RNR technology hub being left fallow. It was more worrying to observe that more and more wetlands are left uncultivated annually. This trend was indeed not very encouraging in view of the Ministry of Agricultures' (MoA) policy objectives of household food security and self sufficiency. For an institution like RNR RC Wengkhar which is mandated to provide the lead in developing suitable technologies to support the farmers, there could be nothing more embarrassing than to see the communities in the vicinity abandoning to grow their most preferred food grain. This situation sparked the idea of rejuvenating the farmers to encourage and revive the cultivation of fallow wetland land. Our interactions with the farmers brought to the conclusion that there were social and technical factors that led to the increasing fallow wetland.

In order to address these issues, a multi-dimensional research outreach program was started in consultation with the communities, local leaders, district extension and JICA experts. The underlying objective of this research outreach program was to encourage and rejuvenate farmers to cultivate the wetland left fallow through provision of variety of support in the form of a multi dimensional research outreach program which covered provisions of technological options, various forms of direct support services like inputs and community mobilization.

MATERIALS AND METHODS

This research outreach program adopted a two tier implementation mechanism. The immediate start was made through action research on participatory variety selection, community based pest control and organisation of farmers into groups. This was more informal and had more research elements. As the communities became aware and started to appreciate our efforts, a more comprehensive package of interventions was designed. This package was formally presented to the local leaders and the communities and a consensus was finally reached on the proposed interventions, The field crops researchers coordinated the implementation by drawing support from all the appropriate sectors in providing the technical options while, the researchers in Research Communications sector facilitated the participation of farmers and extension staff in the program and also looked at addressing social issues through the organisation of farmers into groups and facilitating them to farm together.

Rice outreach program

Key features of the research outreach program

Despite the mismatch in Nark's research mandate, this outreach program was designed consciously to provide direct support to the farmers. As the key objective was to rejuvenate the farmers it was felt that initial provision of direct support would influence their active participation. The direct support was provided in the forms of free inputs, basic infrastructure and direct technical intervention by researchers. Besides the direct support, unlimited access to improved technologies, technical backstopping to organise the communities and capacity building were provided by RNR RC. The research interventions were not limited to rice alone as it also attempted intensification of the use of wetland through winter cropping with vegetables, potato and wheat.

Understanding of causes of increasing fallow wetland and interventions

To establish and understand the critical factors influencing farmers to

abandon the wetland cultivation, a series of consultative meetings were held with the communities lead by the research communications sector. These meetings were not organised solely for the identification of causes but in attempting to organise the communities into functional groups. The issues were then finally agreed on a plenary session at the time of the presentation of the outreach program proposal. The following social and technical reasons were stated as the main factors responsible for declining interest on rice cultivation.

Reasons influencing the abandoning of rice cultivation in Wengkhar

The reasons categorised into social and technical groups are discussed in the following sections.

a) Social reasons

The important social reasons that influenced the decline in wetland cultivation included:

i) Size of land holding and extent of fragmentation

The total wetland area at Wengkhar for this research is about 36 acres. There are two contiguous blocks with the RNR Research centre in the middle. The size of wetland at Wengkhar is not very huge. What is very unique is that it is owned by farmers from more than six different villages. This exemplifies the importance of owning a wetland. The extent of land fragmentation is immeasurable and there are over 40 households from six different villages who own the wetlands at Wengkhar. The size of the land holding ranges from just a single terrace to few acres. The land fragmentation has occurred as a result of family disintegration and distribution of property to the children.

ii) Distance to the rice field from their homestead

With land owners scattered in different villages, the distance from their homestead to the rice fields varies from 10-15 minutes to 2-3 hours walk. This imposes several difficulties in enabling to undertake sound farming practices. For instance the

allocation of Farm Yard Manure(FYM) is often based on the distance to the farm. Therefore wetlands being relatively far do not receive any FYM. The farm nearest to the house is also the safest in terms of the risks of damage by wild pest. According to farmers, the shortage of farm labour is a reality and strategically it is best to concentrate on the farms closest to the house.

iii) Non resident owners

The decision to cultivate or not to cultivate ones registered land lies with the owner. Any individual farmer would have his or her rightful justification to leave the land fallow. However, this decision has a serious implication on fellow farmers who toil hard and depend on their land. As more and more farmers opt to discontinue cultivating their land, it encourages the build up of pests, disease and wild animals. This has consequences on the fellow permanent farmers.

iv) Traditional share cropping practices

Farmers have been dynamic in adjusting their strategies with the change in time but surprisingly the traditional share cropping practices have remained unchanged. At Wengkhar 50:50 is the most dominant system of share cropping. At the present context of acute farm labour shortage, high incidences of pest and diseases, social problems and the abundant availability of imported rice, such a system of share cropping seems no longer economically attractive.

b) Technical reasons

Farmers cited three important technical reasons that influenced the abandoning of rice cultivation. The three reasons are increasing incidences of pest and diseases, low productivity as a result of poor soil fertility and water shortage and dependence on traditional varieties.

i) Increasing incidences of pest and diseases

Farmers went on to list a number of pests and diseases damaging their rice crop. Of them Leaf folder also known as leaf roller - *Cnaphalocrocis medinalis* had become the most threatening

problem. The magnitude of leaf roller attack seems to have increased over a period of time.

ii) Low productivity as a result of gradual decline of soil fertility

Being far from the house, the wetlands receive a step motherly treatment as compared to other types of land. There is virtually no application of inputs of any forms in these lands. Land preparation, transplanting and crop management practices are grossly inadequate. No other options of soil nutrient management are practiced and as a result of this production per unit area was on the decline. Although farmers mentioned irrigation as the key problem, it is not as acute as stated. The main irrigation source is the Yakpugang stream which is sufficiently recharged by the monsoon. Delays in the monsoon, large conveyance losses and inefficient water use practices are of some concern.

iii) Dependence on traditional rice varieties

The entire area is cultivated to local varieties. These varieties have an inherent low yield potential besides being highly susceptible to lodging and pest attack. There choice is limited and farmers grow only two local varieties namely Nakila and Tongsarpa.

Interventions under the Research Outreach Program

The interventions under this outreach program were designed to address the technical constraints and social issues. To address the technical constraints an attempt was made to replicate the station successes in the farmer's field. The technical interventions are discussed below.

a) Technical Interventions

Technical interventions included those that directly helped to address the production constraints like pest problem, soil fertility and labour shortages. As one of the objectives was the rejuvenation of the farmers, the technical intervention also had some hardware elements like

infrastructure developments.

i) Control of Leaf Folder

This was the most immediate need of the hour. As was mentioned earlier this interventions began much ahead of the formal research out reach program. The pressure of leaf folder was first reported from 2002 rice season. RNR RC responded immediately by initiating a joint control program with the communities. The chemicals, spray machines, fuel and technical expertise was provided by the researchers while the communities contributed the labour for spraying. It was continued for three seasons.

ii) Improved crop management

As the production per unit was low due to the marginal management practices, free inputs (fertilizer and weedicide) were supplied by RNR RC. Recommended amount of chemical fertilizers and weedicides were supplied free for two years. Researchers also demonstrated the use of inputs by working along side the farmers. Time and methods of input uses were practically demonstrated. Hands on trainings were provided for seed selection and storage. For the supply of inputs alone, at least up to Nu. 10,000.00 were invested annually and in 2005 season it was increased to Nu. 25,000.00.

iii) Farm Mechanization

Much of the operations within the research farm are at least semi-mechanized. This was replicated in the farmer's field. The main activities under this scheme were the supply of power tillers for three groups, construction of 2.5 km power tiller road traversing the whole rice field, demonstration of labour saving deceives such as pedal thresher and training of three power tiller operators. Although RNRRC did not provide any direct monetary support for the purchase of power tiller, it assisted in the procurement of the power tiller in various ways. RNRRC negotiated for power tiller supply on behalf of the three farmers groups with the Department of Agriculture acting as a guarantor for the groups for which they received a grace period of six months to deposit

the cost. We also helped in the training of three power tiller operators at Agriculture Machinery Center at Paro. With the assistance of the JICA funded project 2.5 km power tiller tract was built to facilitate farm mechanization. In addition cement, hume pipes and other materials were also supplied for improving the power tiller track.

iii) Participatory evaluation of high yielding varieties

Many farmers had started to appreciate the performance of new rice varieties grown at the research farm close to their field. Depending on their willingness, farmers were given two options. They were provided seeds for which they could raise nursery and plant on their own while others who preferred to take only the seedlings could do so by taking the seedlings from the research farm. Later seedlings were raised in the farmers field itself. Two new varieties were tried in larger scale while other varieties were evaluated as on farm trials.

iv) Land use intensification

The basic aim under this activity was to increase wetland use intensity so that it gets adequate allocation of resources like FYM to improve its management. The present cropping sequence followed is rice-fallow and no inputs are used. By supporting the cultivation of winter crops like potato, vegetables and wheat it was intended to improve the management of wetland.

b) Social Interventions

The social interventions comprised more of software elements through which the production constraints could be better addressed. It focussed on group promotion, saving schemes and group farming.\

i) Consolidation of farmers into Groups

Organizing farmers into groups was pursued with the lead by the Research Communication Sector. The main objective was to establish viable farmer's groups that would make effective utilization of capital investments such as power tillers and power tiller tracks. Group formation primarily focussed on production

and marketing to inject the idea of commercial agriculture. A Group bye-law was developed and rigorous support was provided on developing power tiller sharing mechanism among members, maximisation of its utilization as a group property to generate group fund and record keeping. Three functional groups were formed which started to function.

ii) Group saving scheme

Lack of group funds has often been a serious bottleneck for group sustainability. The idea of a group saving scheme was presented and saving schemes were formally opened with the Bank of Bhutan.

iii) Group farming

An attempt was made to mould and integrate the communities to work together by pooling resources while still maintaining the individual contribution through an internal mechanism. Availability of resources such as farm labour varies among households. Some household are well off in labour force but lack financial resources. The idea of pooling resources was tested. Land pooling although not in its absolute terms of actual physical pooling was done by bringing the groups to work on one parcel. Most farmers were very forth coming to pool resources for infrastructure developments like the power tiller track.

RESULTS AND DISCUSSION

The outreach program of this nature and scale in rice commodity was the first of its kind undertaken by RNR RC Wengkhar. It was formidable for three main reasons. First it contradicted with the institutions research mandate as there were substantial development elements inbuilt in the outreach program. Secondly, it involved working with three different farmers groups and non group farmers. Thirdly it entailed social interventions which are not often as mechanical as technology evaluation.

The ultimate objective of increasing the area under rice through re-cultivating fallow land at Wengkhar could not be achieved and in essence the attempt through the outreach program was not successful.

This in absolute assessment does negate the amount of resources invested. However, a more careful analysis shows that there were other substantial benefits and learning points for the future. The successes and failures are discussed below.

Successes and failures of technical interventions

The different technical interventions made the intended difference.

- Three years of continuous community focussed leaf folder control was very effective and in 2005 season no spraying was required.
- Farmers were convinced with the increase on yield increase obtained as a result of use of inputs. Weedicide, as an alternative labour saving option was demonstrated and the yield comparison before and after the outreach program shows a positive trend (see Table1).

Table 1. Yield comparison before and after the interventions

Variety	Yield t ha $^{-1}$ in 2003 Before the Program	Yield t ha $^{-1}$ in 2005 After the Program
Khumal 6	2.91	4.89
Nakila	2.11	3.58

- It was possible to replicate the station success in terms of new variety and yield. With improved management practices, it was possible to increase yield under farmers condition (see Table 2). A participatory assessment of technologies was done and the new technical options have been appreciated by the farmers.

Table 2: An estimation of replication of on station success in the farmers field in 2004

Varieties	**On station yield tha-1 (A)**	**On farm yield tha-1 (B)**	**% Achievement of station Yield (B/A X 100)**
Khumal 4	4.15	3.39	82
Khumal 6	4.52	2.91	64
Khumal 6	4.52	4.46	99
Yusiray maap	4.07	1.35	33
Nakila	2.89	2.11	73

- Committed infrastructures (2.5 km power tiller track) were built jointly and three power tillers have been purchased by the farmers groups. Despite very small land holding farmers agreed to sacrifice some parts of their land for power tiller track development. This has facilitated farm mechanization and it is notable to see that power tillers are already being used for rice transplanting. The groups are also hiring out the power tiller to other farmers. The power tiller is also serving as an excellent means for transportation of farm products to the Mongar vegetable market.
- The objective to intensify the wetland use was demonstrated but the uptake and continuity is poor. No indication of change in the management of wetland is evident as a result of introduction of commercial crops like potato.
- Farming technologies (new varieties, mechanisation, improved management) which many feel can encourage fallow land cultivation do not work. And therefore there had not been any decline in the fallow wetlands of Wengkhar.

Successes and failures of social interventions

Although it is difficult to exhibit the success and failures explicitly, there are evidences that social interventions were meaningful.

- Through our support three functional groups namely Bumpa, Dungkar and Khorlo have been made operational. The most important benefit of organising farmers has been the ability to purchase three power tillers for each group. Individually, owning a

power tiller would have remained a dream for them. Pooling resources was much easier when negotiated at the group level than at the household. It was also convenient to organise trainings and demonstration to the groups. However, the main failure was that all the wetland owners could not be consolidated and linked with the groups.

- The group saving scheme could be started along with activities generating group funds. Book keeping and power tiller sharing mechanism were also put in place. One of the problems has been that the groups have remained inactive.
- The idea to farm in a group was tested. Farmers contributed resources for the group and infrastructure. Farmers produced and sold products to increase group fund. The groups were also keen to venture into the cultivation of wetland of non resident owners but it could not materialize in the absence of a sound benefit sharing mechanism between the absentee owners and groups. Lack of a strong legal framework and assurance was an area of concern for the groups to invest their resources.

Learning Points

The following are some critical lessons learnt for consideration in developing future commodity programs.

For Farmers

- Realizing the competition for scare resources -As farmer's demand for support is increasing, it is time that the farmers realize the competition for scarce resources. If the communities do not make use of the opportunities resources can easily slip off to others.
- Farmers could derive more benefit by organising themselves into groups rather than remaining as individual entities. What farmers must understand is the magnitude of advantages against small inconveniences in joining a group.

For the researchers and extension personals

- It is clear that technology options alone are not adequate. In this case the main reason for not accomplishing of the target was due to

the absentee owners who could not be drawn into the program. There was no designated representative who could take decisions on their behalf which at the end impeded the programs. Absentee owners are an issue that requires careful consideration for the success in future programs. The support of the District Adminstration, Mongar, was sought but despite their effort nothing concrete could be done in the absence of land owners.

- Research Outreach program of this scale and nature can be very effective to demonstrate impact rapidly if focussed in a potential area. Researchers, extension and local leaders can come in one platform to focus on an issue. The key merits are effective cost sharing, implementation of a full package of interventions and quick results.
- An urgent attention is required on reviewing the traditional share cropping mechanisms. Unlike in the past where owning and cultivating wetland used to be prestigious, it is no longer the case as options for buying rice are available. If a more economically advantageous system is worked out and backed by legal enforcement, percentages of fallow land cultivation could be increased through share cropping by willing farmers.
- Community approach to address common issues like pest control, community crop guarding; resource pooling can be a very effective strategy if pursued consistently through cost sharing and group farming concepts.

CONCLUSIONS

Although the ultimate target of increasing the percentage of wetland cultivation could not be achieved, this research outreach program was very useful in understanding the social reasons behind increasing fallow wetland and helped us to understand that paddy research should also try and look at the social aspects since technology in the form of variety, farm mechanisation and improved management etc is not the ultimate answer for fallow wetland. We need to address the deeper social issues attached with wetlands.

It has also given some indication that group farming has a potential if it is carefully targeted. However, group farming in itself needs to be

looked at with a focussed approach. It needs continuous support and facilitation beyond the type and level of services provided by research and extension currently.

While the outreach concept has not been able to address the fallow wetland problems, the program was successful in promoting the technologies. Fertiliser application and pest and weed control thorough chemical has been picked up. Two new rice varieties (*Wengkhar ray kap and Khangma ray kap*) have gained its popularity in the study area for those farmers who cultivate their land. Several successes discussed above also shows that an approach of this nature merits scaling up in potential areas for promotion of research technologies. This study also indicates that social research as a huge area for RNR RCs to look at than just developing new varieties.

ACKNOWLEDGEMENT

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Horticulture

Top-working: The best method for walnut orchard development in Bhutan

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ABSTRACT

Walnut – Juglans regia, industry in Bhutan is small and planting materials are developed as of now from seeds resulting to a huge ***variation*** *in the orchard yields and nut quality. In this walnut top-working observation trial, local walnut seedlings are transplanted in the production field along with the nursery grafted walnut trees as a check. Local walnut seedling trees were then top-worked with improved cultivars when they are about 2 to 3 years old. Farmers' walnut trees producing poor quality nuts were also top-worked in west-central region. The dormant scion wood was cut from parent tree much earlier, waxed and stored in refrigerator (4°C) after proper packing. Bark grafting was practiced both for top-working and frame-working or grafting of branches by the late in the spring season (end of March to April) or when new growth has taken place. Graft take, survival, plant growth vigor and precocity (earliness to fruit bearing) were observed both for nursery grafted orchard trees and seedling orchards and then top-worked trees.*

Graft success rate achieved has been as high as 90% in top-working in an altitude range of 1300masl to 2300masl. Plant growth was vigorous and fruiting commences after 2-3 years of top-working in this altitude range regardless of the age of the stock trees while nursery grafted trees in the orchard are yet to fruit. Frame-working or grafting of branches was desirable compare to top-working for grown up trees. Top-working is an appropriate and easy method for the conversion of local wild walnut seedlings into production of commercial plants or inferior cultivars to improve ones or to provide pollenizer. The planting of wild local walnut seedlings in the production field and latter top-

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working with desired scion cultivars is the best for walnut orchard development in majority of potential walnut production area in the country (area with elevation of 1300 to 2300masl). However, this same technique of walnut orchard development in the country cannot be practiced in an area with elevation above 2300masl due to unsuitable temperature for walnut grafting. In such areas, nursery grafted walnut seedlings should be used as the planting materials for walnut orchard development.

KEYWORDS:

Walnut, scion, rootstock, seedlings, top-working, frame-working, sap bleeding, orchard, graft, altitudes, elevation.

INTRODUCTION

Walnut orchard development though small in Bhutan has gained momentum with the commencement of 8th five year plan as it appeared as one of the priority commodities for the horticulture development in the country. The walnut orchard is being developed as of now from seeds that have resulted to a **huge variation** in the orchard yields, nut size and quality. These seeds were probably imported from India, Tibet, European countries and America. The grafting techniques have been studied and successfully demonstrated for use by the Druk Seed Co-operation and Private Nursery Growers but there is no walnut mother plants established anywhere in the country to be used as a scion wood for vegetative propagation (G. Tshering, personal communication, 2004). In eastern and central Bhutan, private nursery operators are being promoted by Ministry of Agriculture and they are producing and supplying soft-shell walnut seedlings through Districts to the farmers for orchard establishment. But we need to discourage the supplying of seedlings to the growers so as to avoid undesirable inherent characteristics of seedling plants (> 50% of soft shell seedling orchard produces hard shell walnut) and to derive the benefit of uniformity, precocity and trueness to type of the grafted plants. If seedlings are to be supplied to the farmers, it has to be done in large scale and develop walnut orchard in a concerted areas so that it will be easy to top-work them with superior soft-shell walnut when they are 2-3 years old.

Inadequate outstanding cultivar (mother plants) as the source of scion wood for mass grafting is the biggest constraints in the development of walnut industry in the country. However, recently horticulture research programme had selected 17 good cultivars of soft shell walnut from the open pollinated seedling trees or local diversity across different agro-ecological zones and two superior cultivars released for general cultivation. This cultivars needs to be grafted and planted as a walnut mother plants for scion wood production. Therefore, it is important for the research institute to look into the possibilities of identifying walnut production technology which is easy, quick and economical without loosing much time while the "National Walnut Mother Plants' for scion wood production are being established in research centre, DSC and private nursery growers. To this end, an observation trial on top-working of existing and new seedlings walnut orchards was done.

Top-working is a process when comparatively older rootstocks are grafted or budded at the higher level (1m above the ground) in the production field. It is usually adopted for the conversion of wild large seedlings into production of commercial plants or inferior cultivars to improved ones or to provide pollenizers.

MATERIALS AND METHODS

The dormant scion wood of improved and released cultivars (Kanthel selection & Yusipang-2) was cut from parent tree quite in advance, waxed and stored in the refrigerator at 4^{o}C after proper packing till the time of top-working in mid of March for lower elevation (1300-1899masl) and in second week of April in higher elevation (1900-2300masl). Varying age of 2 to 10 years old local walnut seedlings trees (*J. regia*) in the farmers' orchards which are of poor quality and hard-shell were top-worked with improved cultivars. The plants to be top-worked were growing actively at the time of top-working. Top-working was done for younger trees while frame-working or grafting of branches was done for older trees. Three to five branches with wide angles and the projection in all the directions are retained and frame-worked. The other branches on the tree were removed.

Two approaches of walnut orchard improvement and development

were studied in the farmers' field. First, the existing local walnut or improved seedling trees which have turn out to be hard-shelled were top-worked. In the second approach, local hard-shell walnut (*J. regia*) seedlings were transplanted in the orchard and top-worked when they are 2 years old. Nursery grafted walnut trees were planted along the seedling trees so as to serve as control.

Bark grafting was used as a technique for top-working and frame-working. After bark grafting, the open wounds were covered by the grafting wax and in some cases re-waxing was done. The graft union portions were wrapped with thick polyethylene plastic and stump were white washed to protect from the sun burn. The suckers or water shoot from stock were removed as and when it appears. Staking of the successful top-worked plants was done to avoid breakage by strong wind. The plastic covering the graft union were removed once the union formation is complete and growth constriction is visible by releasing the pressure of successful union by cutting the plastic from one side.

RESULTS AND DISCUSSION

The frame working of walnut seedling trees resulted in 90% graft take while top-working particularly younger trees resulted to graft take of 85-90% and of about 70-80% for older trees in altitudes of 1300mals to 2300masl. Fruiting commences after 2-3 years of top-working in altitude of 1300masl to 2300mals regardless of the age of the stock trees. Frame-working or grafting of branches is desirable in comparison to top-working of grown up trees, for quicker healing of wounds, higher graft take, earlier production and higher yields.Added advantages of top-working are, since the rootstock is already well established, the scions make rapid growth and commences bearing earlier than the nursery grafted and transplanted trees. Low survival rate and slow growth were observed for the nursery grafted walnut plants and then transplanted in the production field. Domestic animals damage was prominent on the top-worked trees prior to completion of graft union formation than the nursery grafted trees.

Sap bleeding is a problem in walnut top-working especially when it is done in early spring which can be avoided by heading back the stock

before two weeks of actual operation, complimented by withholding irrigation. In severe cases the slanting cuts through bark into the wood can be made on the rootstock just below the grafting point; if any bleeding in future, it occurs through these cuts after grafting.

CONCLUSIONS

Since a large number of young seedlings trees producing inferior quality nuts are abundant in the farmers' field combined with low survival rate and slow growth of nursery grafted or budded plants. Top-working seems to be an appropriate and useful choice for reaching the newly released superior cultivars to the farmers for improving the poor quality producing orchards and also for new walnut orchard development. Top-working is the best method for seedling trees between 2-5 years old and frame-working for seedling trees above 5 years old, where wound healing is easier, higher percentage of graft take, earlier production and higher yield were obtained compared to nursery grafted and transplanted trees.

It is best to plant the wild local walnut seedlings in the production field and latter top-working with desired scion cultivar for walnut orchard development in majority of potential walnut production area in the country (area with elevation of 1300 to 2300masl). However, this same technique of walnut orchard development in the country cannot be practiced in an area with elevation above 2300mmasl due to unsuitable temperature for walnut grafting (top-working). In such areas, nursery grafted walnut seedlings should be used as the planting materials for walnut orchard development.

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General

Adjusting methodologies to improve the relevancy of research – A case of technology evaluation and demonstration in rice.

Tirtha Bdr Katwal[1], N.B Adhikar[2] and Toyozo Tanaka[3]

ABSTRACT

The primary role of research in the Bhutanese context is to undertake adaptive research and generate appropriate technologies and information that could be effectively utilized towards the enhancement of production and productivity of renewable natural resources. Ideally it is expected that research system generates the technologies for the extension to disseminate and farmers are expected to adopt them ultimately bringing about a change in the production and productivity. Experiences have shown that such a mechanism produces a much lesser impact than anticipated. Inadequate involvement of research clients in the technology generation process have been cited as the key reason for poor adoption of technologies and there by its limited impact. Recognizing this bottleneck, RNR RC Wengkhar has attempted to adjust its methodologies through a Focus Village Program that brings research and its clients in one platform. This paper attempts to exemplify the adjustment of methodologies through a case study on rice at Tangmachu, under Lhuentse District in eastern Bhutan.

KEYWORDS:

adaptive research, adjust approaches and methodologies, research, extension - farmer linkages, and focus village program, model Block, joint assessment and demonstration, optional strategy

INTRODUCTION

One of the primary function of the Renewable Natural Resources Research Centre (RNR RC) Wengkhar is to undertake adaptive

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research. The research undertaken is expected to identify appropriate technologies and generate information that could be effectively utilized towards the enhancement of production and productivity of RNR sector both regionally and nationally. Although, the stringent definition of research would restrict RNR RC's role to the evaluation of technologies alone yet for the identification of effective technologies that are acceptable and useful to the clients extends the horizon of its responsibility much further. Our past experiences in limiting our roles solely to technology generation and leaving the demonstration and dissemination of the technologies in the hands of extension has been found to be produce much lesser impact than expected. Grobben (1999) has found that the transfer of skills and knowledge through participatory approaches to be more effective than the passing of ready to use technology as done in the conventional practice. It has often been stated that the usefulness and impact of research at the farmers level is insignificant and the gaps between research and extension is widening.

In keeping with these concerns, RNR RC Wengkhar has been earnestly attempting to adjust its strategies and approaches to make research most relevant to its clients particularly the farmers. In 2004, the Agricultural Research and Extension Support Project in Mongar and Lhuentse districts funded by JICA was started. This project essentially supports both research and extension activities in the two districts. Activities in horticulture and rice were identified as the main areas of support. One of the approaches this project adopted was the development of model area for increased agriculture production through evaluation and demonstration of improved production technologies. The research activities were initially targeted in selected blocks known as the model blocks. These model blocks are ultimately expected to serve as the on-farm sites for technology evaluation and practical disseminations involving research, extension and farmers. One of the key theme in this approach was to conduct research and at the same time provide technical trainings, conduct demonstrations of proven technologies without the need to make another demonstration separately as done in the past. We termed the new approach as the Focus Village Program (RNR RC, 2004). The Focus Village Program basically attempted to focus its research and development activities in

selected sites that presented the best chance for success of new technologies tested in terms of agro climatic conditions and other required resources.

Accordingly, Menbi block was identified as one of the model block and Tangmachu village which has a good potential for increasing rice production was selected as the focus research site for evaluation and demonstration of improved rice production technologies in the 2005 cropping season. According to the RNR Statistic 2004, Menbi block has 128.62 acres under paddy and the average yield is 974 kg per acre.

MATERIALS AND METHODS

The first step was the discussion of the concept with the Extension staff of Lhuentse district. The district and block Extension staff were presented the concept of Focus Village Program which entails testing of technologies, demonstrations of successful technologies and innovations and at the same time their demonstration and promotion. With the concurrence of the cistrict Extension on the concept of Focus Village Program, identification of the site and farmers were done. The critical criteria followed for selecting the trial site was its location. Since demonstration was a key objective the site selected had to be in a commanding area surrounded by other rice fields and easily visible to anyone passing through the village. A manageable area approximately measuring 2 ha cultivated by Mr. Namgay Dorji, Mrs. Yeshi Wangmo and Tangmachu Middle Secondary School was selected. The selected site was leased in for one season. A formal agreement that clearly outlined the responsibilities of RC Wengkhar and the farmers were developed. The key feature of the agreement was that JICA Project and RNR RC Wengkhar as the lessee provided all the inputs, improved technologies and partially compensated for the labour contributed by the farmers. The farmers as the lessor agreed to try the new technologies and received the entire produce at the time of harvest. No separate lease fees were to be paid to the farmers as the entire amount of the final produce would go to the farmer. However, to assure them of the potential risk entailed in evaluation of new technologies, a clause was included in the agreement which stated that RNR RC would compensate them in the event of crop failure as a result of

evaluating new technologies assuming that all other factors were stable. The details of new technologies tested and demonstration conducted are described in detail below.

Improved technologies

The evaluation of improved technologies included evaluation of new rice varieties, techniques of nursery establishment, rate and time of application of chemical fertilizer and scheduling of nitrogen fertilizer, line planting using marker and control of *Sochum (Potomegaton spp.*) using new weedicide Apritop A.

i. Evaluation of improved rice varieties - Two new rice varieties tried were Khumal 2 and Khumal 6. Khumal 2 is provisionally released for the eastern region but Khumal 6 is in the advanced stage of evaluation.

ii. Improved nursery establishment- Farmers normally raise their seedlings under upland conditions and the age of the seedlings is normally over 45 days old. Seed rate and the duration of nursery under the local techniques is normally high. In the improved method, nursery was established on raised bed in the rice terrace and seeds were sown in line at a spacing of 15- 20 cm . Seed was sown at a depth of 3 cm at the rate of 100 gm/ m^2. Urea was applied between the lines at the rate of 0.5 kg/100 m^2 .

iii. Rate and time of application of chemical fertilizer and scheduling of nitrogen fertilizer application – except for some small amount urea, farmers do not apply other chemical fertilizers. There is also little knowledge on the rate, time and method of fertilizer application. Under the improved management, the recommended rate of chemical fertilizer was applied at the rate of 70:40:20 N:P:K kg ha-1. The entire amount of phosphorous, potash and 60 kg nitrogen was applied at transplanting while the remaining 40 kg nitrogen was split into two equal halves with 20 kg ha^{-1} applied as first top

dressing about one week before panicle initiation (30 days after transplanting) and the remaining 20 kg ha^{-1} two weeks before flowering (60 days after transplanting).

iv. Line planting using marker – line planting has been demonstrated in the past but farmers feel that stretching a rope just requires additional labour and the advantages of line planting are minimal. Improved transplanting technique using markers was tested. The lines were marked with a wooden marker which was locally fabricated. The marker is a simple device with wooden wheel that can be dragged on the puddled paddies to mark lines on which seedlings can be transplanted. It can make 2 pairs of lines with the line to line spacing of 21cm and the distance between the pair is 36 cm. The main advantage of this marker is that one person can mark the lines without having to stretch ropes.

v. Control of *Shochum (Potomageton spp.)* - *Sochum* (*Potomegaton spp*) is one of most serious weed in Tangmachu and to manage the problem of *shochum* one immediate and one long term techniques were tried. The immediate technology tested was the use of weedicide Apritop A imported form Japan. This weedicide was applied at a rate of 10 kg ha^{-1} and the cost of the weedicide is Nu 1800 per kg. For the long term, *Shochum* management by direct seeding under upland conditions was evaluated. This was tried because the growth conditions required for *Shochum* is similar to rice and altering the conditions by direct seeding of rice under upland condition could possibly help reduce *Shochum* pressure.

B. Trainings and Demonstrations

Demonstrations and trainings *per se* is not a primary research role. In the Focus Village Program aside from the research role, training and demonstration were also included as the key feature. For accomplishing the research and extension roles, a close collaboration was kept between the research, the extension program unit of RNR RC and the district extension. The details of demonstrations and training are discussed below.

i. Trainings – In total two farmers trainings were conducted in which about 30 farmers participated in each training. The trainings were coincided with the timing of the field activities so that an actual demonstration of techniques was possible. The first training was conducted on seeding and transplanting and the second training included two topics viz. rice field management and fertilization and rice quality, pest and disease management. The contents and focus of each training is briefly highlighted below.

a) Seeding to transplanting - this training covered variety selection, nursery bed preparation, seed preparation, seed sowing and transplanting techniques and outlined the advantages of improved methods.
b) Rice field management and fertilizer application- During this training water management, weed control and rate and time of fertilizer application were the main topics. Timing of fertilizer application especially the scheduling of nitrogen fertilizer was highlighted.
c) Rice quality, pest and disease management- As RNR RC did not have the required expertise in this field, another JICA Expert was hired to study the rice pest and diseases. This topic was dealt by Dr. Yoko in which he highlighted the quality parameters of rice and management tips to achieve these qualities. Under pest and disease management of blast disease, leaf folder and stem borer were covered.

ii. Demonstrations

It included demonstration of techniques as well as the tools and implements such as rotary weeder and pedal thresher. Much of the demonstrations were in built within the training and actual demonstrations were shown. During the time of harvest an elaborate exhibition was organized for 60 farmers including 10 farmers from Minji block. During this field day, the final results and all aspects of cultivation technologies were once again demonstrated through posters and live samples. Farmers were

also asked to assess the difference in production as a result of the adoption of new technologies and compare with the neighbouring farmers field where cultivation were done in a conventional way.

RESULTS AND DISCUSSION

The Focus Village Program had three main objectives viz. testing of new technologies, demonstration of technologies and techniques to the Extension staff and farmers through trainings and by actually working along side the research team; and joint assessment or evaluation of technologies. The results are discussed in line to these three objectives.

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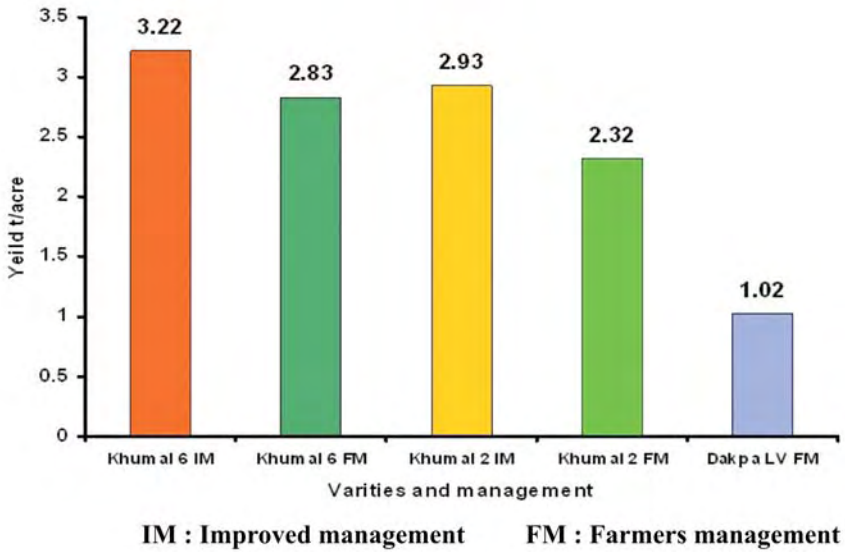
i) Research to evaluate improved rice production technologies

Research included evaluation of new technologies validation and adaptation of existing technologies that are new to the site. Two new rice varieties Khumal 2 and Khumal 6 were evaluated at the site. Their yields were compared under different management techniques. Through the improved nursery raising technique the 30 days old seedlings were transplanted as compared to the 45 days old seedlings used by farmers. This has proven that nursery can be raised in the wetland and time for raising the seedlings can be reduced. The recommended rate and time of fertilizer application was evaluated for that particular location and the tested rates can substantially help to increase the production. *Shochum,* was effectively controlled using a new weedicide Apritop A. Except for its availability and cost, Apritop A can be effective in controlling *Shochum*. The long term effect of direct seeding on *Shochum* needs further observation. The marker was tested under farmers condition for making lines for transplanting. This device can be more effective and requires less labour for line planting as compared to the use of ropes.

To estimate the yield for comparison, random crops cuts were taken from an area of 4 m^2 from both improved and farmers managed practices. The highest yield was recorded for Khumal 6

from improved management practices followed by Khumal 2 (Table 1). Results indicate that these two varieties can be recommended for farmers of Tangmachu. Based on its performance in Tangmachu and other locations Khumal 6 has been proposed for release.

Table 1: Yield comparison of different varieties



ii) Demonstration of technologies and techniques to the extension staff and farmers

Although demonstration and training are not the direct responsibilities of research, they were taken up in the package of the Focus Village Program. The lead in the organizing of demonstration and trainings were taken up by extension program unit of RNR RC while the technical part was handled by the research team. The extension staff of the block were fully engaged in the demonstration of techniques and farmers trainings. The accomplishment of this objective was done through-

- actual demonstrations of improved technologies to the majority of the farmers of the block

- two farmers trainings were conducted
- farmers field day cum exhibition was organised
- development of training materials like charts and posters which could be used by the extension for such trainings in future

iii) Joint Assessment or evaluation of technologies by Research, Extension and farmers

The final part was the joint assessment of the entire program. This was done jointly by the research team, the extension expert , extension program unit of RNR RC, district extension and the farmers. For the joint evaluation a farmers' field cum exhibition was organized. The key objective of the field day cum exhibition were to demonstrate the success of the activities to other farmers including representative from Minji block, jointly assess the activities/technologies demonstrated at the site and disseminate the improved rice management technologies to more farmers. Sixty farmers, heads of the two blocks, school agriculture teachers, and extension staff assessed the program. The summary of the assessments were as under:

- Initially the cooperator farmers felt that production will be low due to the large spacing between lines in the marker method as compared to the farmers method of transplanting. They were however convinced when the crop developed and there was profuse tillering. The marker method of transplanting in lines was found to be more labour saving than farmers method. In this method harvesting was much easier
- Farmers realized the higher yield potential of improved varieties
- District extension appreciated the concept of Focus Village Program which included research, training, demonstration and technology transfer
- The cooperator farmers made a yield comparison before and after the adoption of new technologies (Table 2)

Table 2. Rice Production before and after the adoption of technologies – comparison by co-operator farmers

Name of Cooperator	Production* in 2004 (Before Adoption)	Production in 2005 (After Adoption)
Namgay Dorji	310 Drey** or 465 kg	1080 drey or1620 kg
Yeshi Wangmo	180 Drey or 270 kg	1002 drey or 1503 kg
Tangmachu Middle Secondary School	700 Drey or 1050 kg	2730 drey or 4095 kg

**Production reported is from the same area of 2004 and the area cultivated was equal in both years . **One Drey = 1.5 kg of Paddy*

CONCLUSIONS

Our experience at Tangmachu indicates that the Focus Village Program can serve as an effective optional strategy for adaptive research.. As the approach encompasses both the aspects of research and extension it is effective in forging a stronger research, extension and farmer linkages mainly by way of working together. It is also very effective in reducing the time for technology dissemination without having to make a separate demonstration as done in the conventional way where research first releases the technology and extension then conducts the demonstrations of released technologies and farmers are expected to adopt them. This approach allows the exposure of the extension staff to the full package of the technologies which they can easily scale up and replicate in new sites after having tested in a holistic manner at the model sites. This approach also allows the effective transfer of skills and knowledge to the clients. The skills of the extension staff can be enhanced by working in the field by working along side researchers and experts.

The scare resources both physical and financial can also be effectively shared between research and extension. Ultimately such a joint effort is also more effective and can produce much larger impact of the programs at the field level and can help convince farmers in adopting new technologies.

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Guide to Authors

Standard Structure of Manuscript for publication in the Journal of RNR Bhutan

A. Total length of the article: Maximum 5000 words. However the Editorial Board can make exception.

B. Standard Structure of Manuscript
The following is the standard sequence of the presentation

1.Title:
The first page of each manuscript starts with the title of the paper which should be typed in bold-faced print using both upper and lower case letters and set in the center of the page. The title should be as brief as possible. Abbreviations are not permitted in the title.

2.Author(s) and agency
The names of the author(s) should be written in full. Indications of titles, professorial ranks or other professional titles should not be used.

The address of the agency to which the author belong to shall be written as footnote.

3.Abstract and key words:
The abstract consisting of 150 – 200 words but no more than 200 words. The abstract should summarize pertinent methods and results in a brief but understandable form. The abstract should start with a clear statement of the objectives of the experiment/ research/ study and must conclude with one or two sentences that highlight important conclusions. References are never cited in the abstract.

At the end of the abstract, list up to six key words that best describe the nature of the research. The term "Key Words" is typed in bold-faced print followed by a colon. The first letter of each key word is capitalized and key words are separated by commas.

Key words should include the species, variables tested, and the major response criteria.

4.Introduction
The introduction starts on a new page/paragraph following the abstract. The introduction briefly justifies the research and specifies the hypotheses to be tested. Extensive discussion of relevant literature should be included in the discussion of results, not in the introduction. To minimize length and avoid redundancy, generally no more than three references should be cited to support a specific concept.

Mention of **objectives** of the study or research will be not done under separate heading. It should form a part o the itroduction if necessary as a separate paragraph.

5. Materials and Methods
Other terminology such as methodology shall be not used in place of Method.

General: A clear description or specific original reference is required for all biological, analytical, and statistical procedures used in the experiment. All modifications of procedures must be explained. Diets, animals (breed, sex, age, body weight, and weighing conditions [i.e., with or without restriction of feed and (or) water]), surgical techniques, measurements, and statistical models should be described clearly and fully.

Statistics: Biology should be emphasized, but the use of incorrect or inadequate statistical methods to analyze and interpret biological data is not acceptable. Consultation with a statistician is recommended. Statistical methods commonly used in the animal sciences need not be described in detail, but adequate references should be provided. The statistical model, classes, blocks, and experimental unit must be designated. Any restrictions used in estimating parameters should be defined. Reference to a statistical package without reporting the sources of variation (classes) and other salient features of the analysis, such as covariance or orthogonal contrasts, is not sufficient. A statement of the results of statistical analysis should justify the interpretations and conclusions. When possible, results of similar experiments should be pooled statistically. Do not report a number of similar experiments separately.

6. Results and Discussion
Results (may be written under sub heading) should be presented in tabular form when feasible. The text should explain or elaborate on the tabular data, but numbers should not be repeated extensively within the text. Sufficient data, all with some index of variation attached, should be presented to allow the reader to interpret the results of the experiment.

Discussion (may be written under sub heading) should interpret the results clearly and concisely in terms of biological mechanisms and should integrate literature results with the research findings to provide the reader with a broad base on which to accept or reject the hypotheses tested.

7. Conclusion
This section, consisting of no more than 500 words, follows the discussion and should explain in lay terms, without abbreviations, acronyms, or citations, what the findings of this research are. Though some speculation is permitted, this section should also caution the reader against over extrapolation of results. For manuscripts with direct applications, this section will consist of an interpretive summary.
Recommendations will be not made under this section.

8. Acknowledgement

9. References

C. TABLES:
Tables are used to present numerical data in a self-explanatory manner. They should be intelligible without consulting the text and should not duplicate data already given in the text or in illustrations. Any abbreviation used in a table must be defined in that table. All tables should be cited in the text. Arabic numerals are used to number tables. The table number (i.e. Table 4.) is typed in bold face followed by a period. The title of the table continues on the same line with only the first letter capitalized. Do not use a period at the end of the title. Column headings should have the first letter of each word capitalized while the names of variables are typed with only the first letter capitalized (i.e. Average daily gain).

For numerals less than 1, insert a zero to the left of the decimal point (columns should be set up so that decimal points are aligned if possible). If there are no data for a particular entry, insert a dash. If an explanation is necessary, use an abbreviation in the body of the table (e.g. ND) and explain clearly in footnotes what the abbreviation means.

No lines, only boundary lines will be used, 8 point normal and no colors

D. FIGURES:
- Align the figures horizontally
- Put captions below the figures; 10 point bold
- Abbreviate figure to fig
- No color, but choose different shade that is appropriate for black/white printing

E. REFERENCES CITATION:
The literature references should be arranged alphabetically, typed double spaced, and in the text referred to by author's name and year of publication enclosed in parenthesis, e.g. (Tenzin, 1995). With three or more authors, only the name of the first authors plus et al.. should be given.

Verify the accuracy of cited references. Make sure that references cited in the text are listed in the reference section and vice versa. Check that names and dates are consistent in the text and references. Do not abbreviate journal titles.
References to personal communication will be not accepted.

References should contain: author's last name followed by author's initial(s) (with periods), year, title of article (only first word and proper noun capitalised), journal (not underlined), volume number, and inclusive page numbers. Books and reports must include the name and location of the publisher.

Examples

1. General

Adeyjou, S.K. (1980). The future of tropical agro forestry systems. Commonwealth Forestry Review 59(2): 155-159.

Dukpa, N. (1997). Technical report of Chirata cultivation and collection in Singkhar Lauri. RNR Research Sub-Centre, Mongar

LUPP - Land Use Planning Project. (1994). District data sheets for Samdrup Jongkhar, Ministry of Agriculture, Thimphu, Bhutan.

MOA - Ministry of Agriculture. (1997). Integrated Horticulture Development Project Document. (BHU/97/003/A/01/99).

RNR RC - Renewable Natural Resources Research Center. (1997). The Progress and Achievements of the Seventh Five Year Plan, July 1992 - June 1997. RNR RC East, Khangma, REID, Ministry of Agriculture.

2. Standard Journal Articles:

Jensen, M. S., S. K. Jensen and K. Jakobsen. (1997). Development of digestive enzymes in pigs with emphasis on lipolytic activity in the stomach and pancreas. J. Anim. Sci. 75:437-445.

Jin, C. F., J. H. Kim, H. K. Moon, W. T. Cho, Y. K. Han and I. K. Han. (1998a). Effects of various carbohydrate sources on the growth performance and nutrient utilization in pigs weaned at 21 days of age. Asian-Aust. J. Anim. Sci. 11:285-292.

3. Journal Article with a Subtitle :

Ackerson, R. C. (1981). Osmoregulation in cotton in response to water stress: 1. Alterations in photosynthesis, translocation and ultrastructure. Plant Physiol. 67:484-488.

4. Abstracts and Supplements :

Mahan, D. C., E. M. Weaver and L. E. Russell. (1996). Improved postweaning pig performance by adding NaCl or HCl to diets containing animal plasma. J. Anim. Sci. 74(Suppl. 1):58(Abstr.).

Smith, J. W., M. D. Tokach, R. D. Goodband, J. L. Nelssen, W. B. Nessmith, K. Q. Owen and B. T. Richert. (1995). The effect of increasing zinc oxide supplementation on starter pig growth performance. J. Anim. Sci. 73(Supp. 1):72(Abstr.).

5. Journal Article Accepted but not yet Published :

Li, D. F., J. L. Nelssen, P. G. Reddy, F. Bleccha, R. D. Klemm, D. W. Giesting, J. D. Hancock, G. L. Allee and R. D. Goodband. (1999). Measuring suitability of soybean products for early-weaned pigs with immunological criteria. J. Anim. Sci. (In press).

6. Standard Book :
National Research Council - NRC. (1998). Nutrient Requirements of Swine. 10th Ed. National Academy Press, Washington, DC.

Snedecor, G. W. and W. C. Cochran. (1989). Statistical Methods. 8th Ed. Iowa State University Press, Ames, Iowa.

7. Chapter in an Edited Book :
Cromwell, G. L. (1991). Antimicrobial agents. In: Swine Nutrition (Ed. E. R. Miller, D. E. Ullrey and A. J. Lewis). Butterworth-Heinemann, Stoneham, Massachusetts. pp. 297-314.

Mayes, P. A. (1990). Digestion and absorption. In: Harpers Biochemistry, 22nd Ed. (Ed. R. K. Murray, D. K. Granner, P. A. Mayes and V. W. Rodwell). Appleton & Lange, Norwalk, Conneticut. pp. 580-590.

8. Thesis :
Thacker, P. A. (1981). Effects of Dietary Propionate on Lipid Metabolism in Growing Swine. Ph.D. Thesis, University of Alberta, Edmonton, Alberta.

Trottier, N. L. (1995). Protein Metabolism for the Lactating Sow. Ph.D. Thesis, University of Illinois, Urbana, Illinois.

9. Conference Proceedings :
Goodband, R. D., M. D. Tokach, S. S. Dritz and J. L. Nelssen. (1995). Practical nutrition for the segregated early weaned pig. In: Proceedings of the 1995 Saskatchewan Pork Industry Symposium, Saskatoon, Saskatchewan. pp. 15-22.

Shurson, J., L. Johnston, J. E. Pettigrew and J. Hawton. (1995). Nutrition and the early weaned pig. Proceedings of the Manitoba Swine Seminar. Vol. 9:21-32.

10. Research Reports etc :
Lutz, T. L. and T. S. Stahly. (1996). Dietary folic acid needs of high lean growth pigs. Iowa State University 1997 Swine Research Report. pp. 4-6.

11. On line :
Ota, T.(1993). Dispan: Genetic distance and phylogenetic analysis. Pennslyvania State Unievrsity, University Park, PA, USA.
http://www.bio.psu.edu/People/Faculty/Nei/Lab/Programs.html