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FOREWORD

From the Minister

I am confident that the Triple Gems of the RNR development - Enhancing Productivity; Enhancing Accessibility; Enhancing Marketing has poised the Bhutanese agriculture to take a qualitative and quantitative leap forward.

Subsistence agriculture shall give way to a commercial one, but definitely not at the cost of leaving out marginal farmers from the mainstream. Special focused programme shall be pursued to address the needs of the resource poor thus contributing meaningfully to the poverty alleviation objectives. Niche commodities through organic production for special markets shall be pursued. Both in-country and ex-country market destination shall be explored and established. Easy and cheaper transport of the agriculture produce to markets shall be facilitated through construction of farm roads and power tiller tracts. Specialised commodity production in specific areas shall be supported to achieve the necessary minimum volume for export market. In all these endeavours, it goes without saying that RNR Research shall be called upon to play a major role by providing the necessary technologies.

I have no doubts on RNR Research’s continued contribution to the socio-economic development of the country, particularly in the modernization of the RNR sector. However, time and again it has emerged that the research results are not reaching the clients as much as it should be. We know very well that *a technology* has no meaning unless it gets translated into action in the farmer field. Here I like to urge the Research System to pay heed to these feedbacks and adjust the approaches and programmes as necessary.

I understand that publication of a journal is part and parcel of any research organization for many important reasons. It provides a vital link between the research organization and it’s client and the general public at large, therefore serving as an effective means of transferring technologies to a wider audience. It can also provide a medium to maintain and promote professional relationships

with other similar research organizations. More specifically to our context, it can provide that much needed forum to our researchers and research centers to publish and document their research works and other knowledge and technologies that are continually being developed.

I am happy to note that with this issue, its readership has expanded to include many national, regional and international RNR and allied research institutes and agencies. I like to urge our RNR research system to make full use of these new linkages in strengthening and nurturing our young Research system.

I am also happy to note that henceforth starting from this issue, the Council for RNR Research of Bhutan (CoRRB) is charged with the responsibility of it's regular and timely publication. It's ensured regular publication will go a long way in inculcating the habit of writing in our researchers who tend to be shy on this front.

While expressing my appreciation to all the concerned for making this long overdue issue a reality, I would like to express my sincere wish and hope for a regular and timely publication of the future issues of the Journal of RNR Bhutan. I would also like to wish the Journal of RNR Bhutan to grow and attain international standard in due course of time.

Finally I wish one and all a Very Happy and Prosperous Male Dog Year 2006.

Tashi Delek !

March 2006


Lyonpo Sangay Ngedup
MINISTER

FOREWORD

From the Editor-in-Chief

Welcome to the fourth issue of the Journal of RNR Bhutan. Though there can be no reasons good enough to justify the long overdue publication of this issue, I suspect the repeated structural metamorphosis that the Ministry underwent in the last couple of years definitely contributed to it. Specifically, in the process of re-organization, the mandate for the RNR Journal publication remained undefined, resulting in no action. Henceforth, as mentioned by the Hon'ble Minister in the foreword to this issue, Council for RNR Research of Bhutan (CoRRB) is given this mandate.

In Bhutan, Renewable Natural Resources (RNR) is comprised of three sectors viz: Forestry, Livestock and Agriculture including Horticulture. RNR therefore encompasses plant, animal, microbial, environmental, extension and rural development, sustainability issues and other cross cutting themes.

The mission of the Journal is to provide an avenue for Bhutanese RNR researchers to inform and share their findings with a wider national and international audience and also to document these useful research works. More importantly the Journal is expected to act as a forum for discussing new research ideas and results that can propel the growth of the RNR sector. Though it is primarily targeted to publish research papers on RNR themes carried out by Bhutanese RNR researchers, any original and significant research papers on RNR related subjects regardless of their authors' backgrounds are also published. However, preference will be given to those research works carried out in the country and by Bhutanese RNR researchers in the case of having to make choices due to overwhelming submission of the papers.

With this issue, we are happy to note the expansion of its readership to include many national, regional and international RNR and allied research institutes and agencies. We hope that this will further facilitate the strengthening of the existing professional and institutional ties and give rise to new and mutually useful linkages.

This issue of the Journal contains twelve papers covering various aspects of RNR sector from forest pattern analysis to the physical characterization of Bhutanese yak to the inventory of the dragonflies in Bhutan and many others.

Finally on behalf of the Editorial board, I like to thank the authors for considering this journal to publish their works. I also like to thank all those who served as

reviewers of the manuscripts for giving selflessly of their time to provide critical and useful reviews.

In addition, I also like to thank the Advisor, Dr. Pema Choephyel, the Director of CoRRB and the members of the Editorial Board for their continuous guidance in the publication of this issue.

Last but no the least, I like to express our special gratitude to His Excellency, Lyonpo Sangay Ngedup, the Hon'ble Prime Minister for his vision, guidance, and ceaseless efforts in operationalizing the Triple Gem Policy – the cornerstone of the RNR sector development. In the spirit of the RNR sector's motto – it is our hope that the Journal of RNR Bhutan will also walk it's own share of many many extra miles in the service of the Bhutanese farmers.

Tashi Delek!

A handwritten signature in black ink, reading "Dorji Dhradhul", written in a cursive style. The signature is positioned above a horizontal line.

Dorji Dhradhul
Editor in Chief
March 2006

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Forest Pattern Analysis Along the Topographical and Climatic Gradient of the Dry West and Humid East Slopes of Dochula, Western Bhutan

Wangda P¹ & Ohsawa M²

ABSTRACT

*The contrasting vegetation and climatic conditions on east and west sides of Dochula pass is a unique characteristic of the dry valley ecosystem. Temperature declines faster on the west slope than on the east slope. Moisture condition is the determining factor for the contrasting vegetation. Floristically 66 tree species belonging to 29 families were recorded and these included 3 conifers, 37 evergreen broad-leaved and 26 deciduous broad-leaved species. The dry pine forest of *Pinus wallichiana* and mixed pine-oak forest of *Quercus lanata* occurred on the west slope of Dochula. Contrastingly humid evergreen broad-leaved forest of *Quercus oxyodon*, *Q. lamellosa*, *Q. glauca* and *Castanopsis hystrix* occurred on the east slope. Dochula pass at 3000 m asl under cloud zone dominated by *Tsuga dumosa*, *Betula utilis*, and *Quercus semecarpifolia* divide the two slopes. We conclude that west slope vegetation corresponds to dry west Himalayan type and east slope the humid east Himalayan type, however, this gradually transits to dry west Himalayan type of *Pinus roxburghii* forest towards the dry valley bottom. The diverse forest types found on the west and east slope of Dochula pass can represent as a miniature of whole Himalaya and are the valuable standard pattern of the Himalayan forest types, which needs careful conservation and management.*

KEYWORDS: aspect, evergreen broad-leaved, soil moisture content, lapse rate.

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INTRODUCTION

Mountain forests of the Bhutan Himalaya provide livelihood to over 70 % of the population from non-timber forest products to timber logging. Forests are also important in the protection of watersheds for major hydropower projects, and for the agricultural fields. However these mountain forests are least studied and only a few published scientific literatures are available particularly in the field of forest ecology and climatology. Bhutan's vegetation differentiated into various forest types based on the altitude and the prevailing dominant species currently forms the only scientific database for conservation and management of the forest resources (Grieson & Long 1983; Negi 1983; Sargent 1985; Frei 1985; Ohsawa et al. 1987, 1992, 2002). Ohsawa et al. (1987, 1992, and 2002) conducted several ecological studies covering major forests of Bhutan from sub-tropical type in the southern foot hills to northern high Himalayas and from mid altitude west to east focusing mainly on the evergreen broad-leaved forest and secondary forest succession particularly in the shifting cultivation areas. However, the vegetation along the dry valley slopes was least studied in the Bhutan Himalaya (Sargent 1985; Schweinfurth 1992) including the major dry valleys of the western region. One of the best examples of dry valley vegetation in contrast to humid vegetation is the mountain forest ecosystem covering Thimphu through Dochula pass to Wangdue. Despite the dramatic vegetation change observed between the two slopes there is a limited research study undertaken to clarify the phenomenon of contrasting vegetation between east and west slopes of a mountain. The present study is therefore expected to fill this important information gap.

Area of Study

The study area covers from Semtokha (2200 m asl) of Wangchu valley through Dochula pass (3185 m asl) to Bajo (1250 m asl) along Punatsangchu valley covering the different vegetation types and climatic conditions (Fig. 1A, 3). It includes the contrasting dry valley bottom of *Pinus wallichiana* or blue pine forest on dry west slopes along Wangchu valley (2200 m asl) and wet oak-laurel forest formed around Lamperi on east slopes, and this again change into dry *Pinus roxburghii* or chir pine forest along Punatsangchu valley (1250 m asl). Dochula ridge top (3185 m asl) of humid cool mixed conifer forest (*Tsuga dumosa*, *Betula utilis*, *Quercus semecarpifolia*) divide the two slopes. The climatic conditions in the study area range from dry valley bottom along Wangchu valley to Dochula under cool humid ridge top (3185 m asl) and descending through Lamperi under moist/wet climate (2700 m asl) to dry valley bottom along Punatsangchu (1250 m asl). Thus, we suspect that the forest types are closely related to the climatic change along the

altitudes on two sides of Dochula. This study is guided by the following three objectives:

- To clarify the climatic gradients,
- To compare floristic compositions and structural changes on east and west slopes of Dochula and,
- To correlate the climatic conditions with forest composition and structural changes.

FIELD SURVEY AND DATA COLLECTION

Meteorology and Soil Moisture

Temperature and humidity conditions of the study area were monitored by eight HOBO onsets (temperature and relative air humidity) automated digital data loggers and two KADEC rainfall loggers with hourly recording interval (cf. Fig. 3). Additional meteorological data were gathered from the existing stations of Semtokha, Yusipang, Lumitsawa, Thinlayang and NRTI. The data loggers were installed at Dochula (3185 m asl) within the existing meteorological station, at Lamperi (2700 m asl) near the National Work Force Camp, at Lumitsawa (2250 m asl) and Mendigang (1760 m asl) nearby the farmhouse, at NRTI inside the meteorological station of the institute, and at Bajo inside the meteorological station of RNRRC-Bajo, respectively. Besides other meteorological stations all the data loggers were installed by the Bhutan-Japan collaborative project on “Life zone ecology of Bhutan Himalaya III” since October 1999 and are still continuing recording.

Soil moisture content was measured by Hydro-sense (CD 620 + CS 620) (Campbell Scientific Australia Pty. Ltd.) bearing 12 cm and 20 cm probes. For every plot we measured at least five sites for each probe with a total measurement of ten sample recordings in each plot.

Plot Layout and Tree Inventory

A total of eleven vegetation sampling plots were established from below Yusipang of dry blue pine forest (ca. 2450 m asl) through cool humid mixed conifer forest at Dochula (3185 m asl) to humid evergreen broad-leaved forest at Lamperi (2750 m asl) and again to dry chir pine forest at Lobesa (1520 m asl) corresponding to respective climate data loggers (Fig. 1A, 3). The tree individuals attaining a height of $H \geq 1.3$ m were measured for total height, and diameter at breast height. The plant species occurring within the quadrat were identified following the Flora of

Bhutan (Grierson, A.J.C. & Long, D.G. 1983-2000); Flowers of the Himalaya A supplement (Stainton 1988); Concise Flowers of the Himalaya (Polunin & Stainton 1987) and Flowers of the Himalaya (Polunin & Stainton 1984).

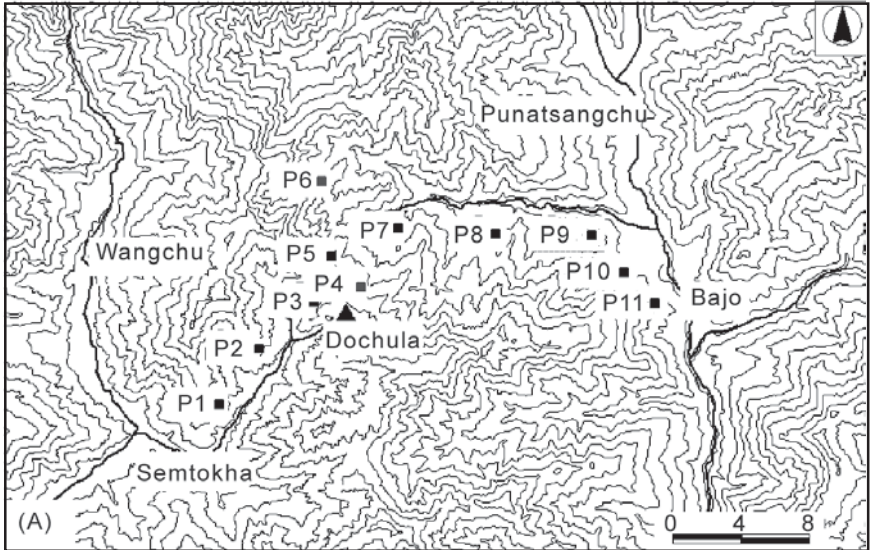


Figure 1: Topographical map of the study area between Wangchu and Punatsangchu valley divided by Dochula and the location of sampling plots (P1-P11) from below Yusipang through Dochula to Lobesa.

Climate Data Analysis

Data loggers were downloaded after every six months with the help of computer-based software program BoxCar Pro 4.3. Data recorded were analyzed based on two standard methods below;

(1) Climatic diagram was drawn by Walter's method (Walter & Lieth 1961-1967, Lieth et al. 1999),

(2) Potential Evapotranspiration Ratio (PER) was calculated by Holdridge's (1969) Equation, $PER = (ABT * 58.93) / PPT$, where, ABT = Annual Bio Temperature ($^{\circ}C$). It is the summation of monthly mean temperature (t) with $0 < t < 30^{\circ}C$ divided by 12 (months), and PPT = mean total annual precipitation (mm)

Vegetation Data Analysis

The vegetation data was analyzed quantitatively using the computer software FOREST program developed by Laboratory of Ecology, Chiba University. Species basal area (BA) was calculated from DBH data of tree individuals and calculated the relative proportion of each species' basal area in percent (RBA %). The RBA of each species was used as abundance of species and the dominant species in each plot were determined by dominance analysis (Ohsawa 1984). In a community dominated by single species, its relative dominance may be stated at 100 %. If, two species share dominance, the relative dominance of each should ideally be 50 %, or if there are three co-dominants, 33.3 %, and so on. The number of dominant species is that which shows the least deviation between the actual relative dominance values and the expected percent share of the corresponding co-dominant-number model.

$$d = 1/N \{E(x_i - x_i^2) + E x_j^2\}$$

$$i ET \quad jEU$$

Where, x_i is the actual percent share (relative basal area) of the top species (T), i.e., in the top dominant in the one-dominant model, or the two top dominants in the two-dominant model and so on; x_2 is the ideal percent share based on the model as mentioned above and x_j is the percent share of the remaining species (U). N is total number of species. Species diversity index (H_2) was calculated by using Shannon & Wiener method.

RESULTS AND DISCUSSIONS

Temperature and Humidity Patterns on West and East Slopes of Dochula

The patterns of decreasing temperature and increasing humidity along the altitudes from Wangchu valley in the west and Punatsangchu valley in the east side of Dochula pass converging at ridge top were studied (cf. Fig. 3). The annual mean temperature decreased faster on the west upslope with an annual mean lapse rate of $0.71 \text{ }^\circ\text{C} \cdot 100 \text{ m}^{-1}$ from $13.5 \text{ }^\circ\text{C}$ at Semtokha (2200 m asl) to $6.5 \text{ }^\circ\text{C}$ at Dochula (3085 m asl) (Fig. 2A). On the contrary the annual mean temperature decreased slower on the east slope with an annual mean lapse rate of $0.62 \text{ }^\circ\text{C} \cdot 100 \text{ m}^{-1}$ from $18.2 \text{ }^\circ\text{C}$ at Bajo (1250 m asl) to $6.5 \text{ }^\circ\text{C}$ at Dochula (3185 m asl) indicating the air is drier along the west slope of Dochula (Fig. 2A). While no appreciable seasonal change in lapse rate was recorded along the west slope of Dochula, the lapse rate (0.57) was lower during summer than dry winter (0.61) along the east slope.

Contrary to temperature, humidity increases along the altitudes from both sides of Dochula. Mean total annual precipitation (mm) increases from 620.4 mm at Semtokha (2200 m asl) and from 645.9 mm at Lobesa (1250 m asl) to 1540.8 mm at Dochula (3185 m asl) indicating both valley bottoms receive fairly same amount of annual precipitation. Similarly relative air humidity (%) and soil moisture content increases from 69.1 %, 20.9 % at 2450 m asl at below Yusipang and from 71.5 %, 13.4 % at Lobesa (1520 m asl) to 93.5 %, 64.4 % at Dochula (3185 m asl) (Fig. 2B). Accordingly potential evapo-transpiration ratio (PER) decreased from 1.3 at Semtokha (2200 m asl) and 1.2 at Lobesa (1250 m asl) under dry conditions to 0.2 at Dochula under humid moist cloud cover ridge top. Interestingly Semtokha (west) and Lumitsawa (east) even though falls on the same altitude (ca. 2200 m asl) shows different PER of 1.3 and 0.8 clarifying the contrasting climatic conditions between west and east slope of Dochula pass.

Temperature and humidity along the west slope revealed steeper gradient indicating relatively drier conditions compared to east slope as indicated by PER. Further soil moisture revealed decisive factor in explaining the difference between east and west slope of Dochula (Fig. 2A, B). A strong inverse correlation (0.86 at $p < 0.05$) between soil moisture content in summer and annual mean temperature exists revealing four types of environmental conditions; i.e.,

- (1) hot dry pine, (2) warm humid broad-leaved, (3) cold humid mixed conifer and, (4) cool dry conifer respectively and correlates to the location and aspect of the study area as shown in figure 2C.
- (2) The clear pattern of seasonal changes of precipitation and temperature is illustrated by Walter's climate diagram on both west and east slopes of Dochula (Fig. 3C1-C8). At Bajo, the dry spells when the valley bottom has undergone water stress for about six months during which the temperature curve remains higher than the monthly mean precipitation curve (Fig. 3C8). The dry spell gradually become shorter to two months in Lumitsawa (Fig. 3C5) and finally on the Dochula ridge top temperature curve remains lower than the precipitation curve throughout the months of the year (Fig. 3C3). On the west slope, Semtokha experiences about five months of dry spell (Fig. 3C1) and this decreases to four months at Yusipang (Fig. 3C2). Thus, such pattern of temperature and humidity strongly affect species distribution and in turn the forest composition and structural changes.

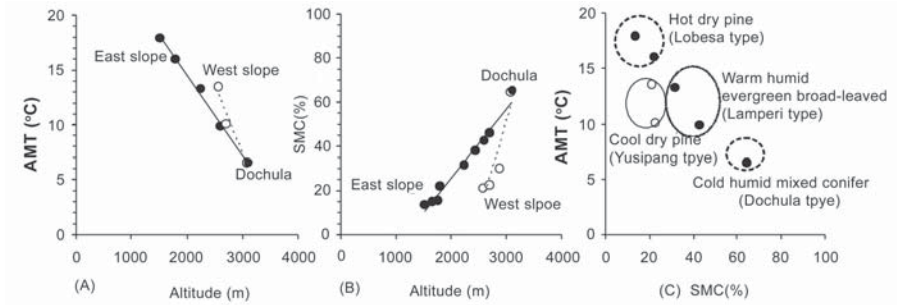
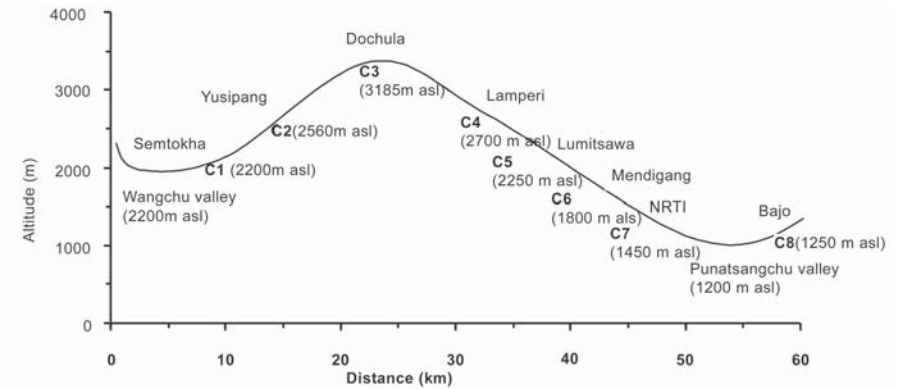


Figure 2: Environmental conditions; (A) annual mean temperature (°C) vs altitude, (B) soil moisture content (%) vs altitude and, (C) temperature vs humidity revealing four environmental types along the topographical and climatic gradients. Open circle = west slope, and closed circle = east slope.



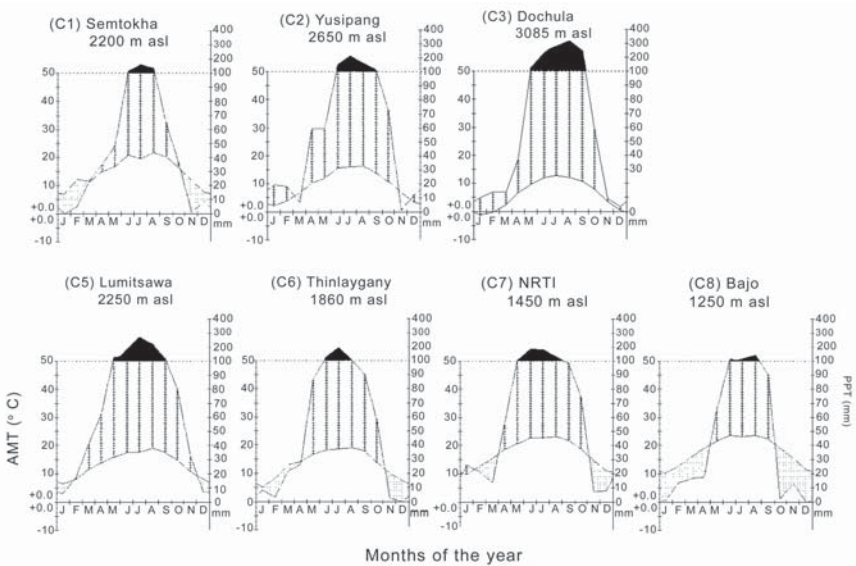


Figure 3: Location of the climate data loggers (C1-C8) and Walter's climate diagram (temperature and precipitation) indicating patterns of dry spells of the study area between the two river valleys of Wangchu and Punatsangchu.

Species Composition, Richness And Climatic Conditions On Both Sides Of Dochula

Based on the analysis of quantitative vegetation data from 11 sampling plots at below Yusipang through Dochula to Lobesa, the floristic composition belonging to 29 families consists of 66 tree species which include 3 conifer trees, 18 evergreen broad-leaved trees, 19 evergreen broad-leaved shrubs, 10 deciduous broad-leaved trees and 16 deciduous broad-leaved shrubs. The dominant families are Fagaceae with 8 species, Ericaceae and Symplocaceae with 7 species each, Lauraceae and Rosaceae with 5 species each followed by Pinaceae, Caprifoliaceae and Euphorbiaceae with 4 species each among others. These 11 plots were classified into four groups by cluster analysis, dominant species and, Holdridge's life-zone classification (Fig. 4, Tab. 1); i.e. (1) cool dry conifer (P1, P2) of Semtokha-Yusipang (type 1), (2) cold humid mixed conifer of Dochula (type 2) (P3), (3) humid evergreen broad-leaved (P4, P5, P6, P7, P8) of Lamperi-Lumitsawa (type 3), and (3) warm dry conifer (P9, P10, P11) of Lobesa (type 4) respectively.

The dominant species of forest type 1 are *Pinus wallichiana* (P1, P2) *Quercus lanata* (P1, P2) (Tab. 1) with a few associated under-story species of dry evergreen *Rhododendron arboreum* (P1, P2), *Berberis aristata* (P2), *Jasminum humile* (P2), and deciduous *Populus rotundifolia* (P2), *Lyonia ovalifolia* (P2).

The forest type 2 is dominated by *Tsuga dumosa*, *Q. semecarpifolia*, *Betula utilis* and associated understory evergreen species of *Ilex crenata*, *I. dipyrena*, *Daphne bhoulia*, and *Symplocos dryophila*. Though top canopy is dominated by tall conifers, understoreys are still dominated by evergreen species.

The species composition of forest type 3 is mainly Fagaceae family. The four dominant humid oaks are *Q. oxyodon* (P4, P6), *Q. glauca* (P5, P6, P8), *Q. lamellosa* (P5, P6), and *Castanopsis hystrix* (P7). The only dry oak *Q. lanata* (P8) occurs in the transition forest at ca. 1800 m asl. Other dominants include evergreen broad-leaved *Rhododendron arboreum* (P8, P9), *R. barbatum* (P4, P6), *Daphniphyllum himalense* (P7), *Schima wallichii* (P8), *I. dipyrena* (P7) and dominant deciduous broad-leaved of *Magnolia campbellii* (P4). Other associated tree species includes 10 evergreen broad-leaved and 5 deciduous broad-leaved. The understory species are mainly dominated by six species of evergreen symplocos; i.e., *S. ramossima* (P4, P5, P6, P7), *S. lucida* (P5, P7, P8), *S. glomerata* (P7, P8), *S. theifolia* (P7), *S. pyrifolia* (P7), *S. sumuntia* (P6, P7) and other species of 8 evergreen, and 6 deciduous species.

The forest type 4 is dominated by only drought and high temperature tolerant *Pinus roxburghii* (P9, P10, and P11). While pure stands of *Pinus roxburghii* dominated the last plot 11 (1520 m asl), the other accompanied species in the transition zones includes evergreen broad-leaved trees of *Q. lanata* (P10), *R. arboreum* (P9), *S. wallichii* (P9, P10), *C. tribuloides* (P9), *Rapanea capitellata* (P10). The associated understory species are of xeric type such as evergreen species of *Berberis aristata*, *V. cylindricum*, *Glochidion velutinum*, and deciduous species of *Benthamedia capitata*, *Zizyphus incurva*, *Phyllanthus emblica*, *P. urinaria* and *Toricellia tiliifolia*.

The life-form spectrum of each forest type was determined based on the relative basal area of their life-forms; evergreen, deciduous, and conifers in each forest community (Fig. 4B). Three distinct life-form spectra, i.e., lower coniferous on both sides of Dochula, mid evergreen broad-leaved on the east slope, mixed deciduous coniferous type at the humid ridge top of Dochula were contrasted (Fig. 4B). It is clarified that no distinct evergreen broad-leaved forest was formed on the west slope of Dochula. However dry evergreen broad-leaved forests of *Q. lanata* and *Q. semecarpifolia* mixed with *P. wallichiana* and *P. spinulosa* were formed on approaching to the humid ridge top of Dochula. Contrastingly well-developed humid evergreen broad-leaved forest was formed on the east slope of Dochula on the same altitude range of the dry west slope.

Distribution of forest composition and life-forms were closely related to the environmental conditions (Fig. 4C, D & 5F). Warm dry *P. roxburghii* forest occurred at the lower altitudes between 1250-2000 m asl along Punatsangchu valley under low soil moisture content (ca. 20 %) and high annual mean temperature (18.2 °C-16.0) (Fig. 4C, D). Humid evergreen broad-leaved forest occurred under high soil moisture content (30-50 %) and moderate annual mean temperature (16-9.8 °C) between 2000-2700 m asl on the east slope. While humid mixed conifer on the mountain top (Dochula) occurred under high soil moisture content (64.4 %) and low annual mean temperature of 6.5 °C. Contrastingly the cool dry conifer of *P. wallichiana* forest occurred at a higher altitude above 2000 m asl to 3000 m asl on the west slope of Dochula under low to moderate soil moisture content (20-30 %) and relatively low temperature from 13.5 at Semtokha to 6.5 °C at Dochula.

The number of species per plot showed unimodal type having peak value of 20 species in plots 7 and 9 under humid evergreen broad-leaved forest on east slope of Dochula and low number of species was recorded in pine forests both at the dry valley bottom of plot 1 under *P. wallichiana* forest (4 species) and in plot 11 under *P. roxburghii* forest (4 species). Similarly the Shannon’s diversity also followed the same trend with a peak value of 3.1 in plot 7 and lower value of 0.7 and 0.1 in plot 2 (west valley bottom) and plot 11 (east valley bottom) respectively. Thus revealing high diversity in the humid broad-leaved forest (Lamperi-Lumitsawa) and relatively low diverse species under cool dry and warm dry conifers respectively.

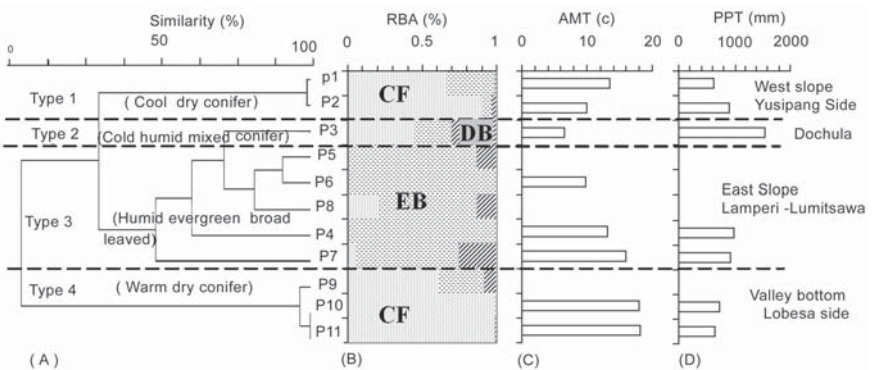


Figure 4: Forest classification and life-distribution along with environmental attributes of annual mean temperature (AMT °C) and mean total annual precipitation (mm): (A) cluster dendrogram, (B) life-form spectrum (RBA), (C) annual mean temperature (°C), and (D) mean total annual precipitation. Note: CF = coniferous, DB = deciduous broad-leaved, and EB = evergreen broad-leaved.

Forest Structural Traits

Forest structural features of eleven vegetation sampling plots on both sides of Dochula were compared to clarify the changes in structural attributes with respond to environmental conditions (Fig. 5A-F). Wangchu valley is ca. 1000 m higher than the Punatsangchu valley though both falls under the same category of dry valleys in the Bhutan Himalaya (Fig. 5A). Ohsawa (1987) called these two types of dry valleys as low and high dry valleys of the Bhutan Himalaya. The former refers to Punatsangchu dry valley type and the latter refers to the Wangchu dry valley type. Maximum height of tree increased from 11.7 m of *P. wallichiana* at 2450 m asl below Yusipang west slope and from 14.6 m of *P. roxburghii* at 1520 m asl at Lobesa east slope to 31.9 m of *T. dumosa* at the converging ridge top Dochula (3185 m asl) (Fig. 5 B). However the height fluctuates around the transition forest around Mendigang (ca. 1800 m asl). This may be attributed to human influence using the forest for extracting firewood and timbers by the nearby village communities. After crossing Mendigang and Lumitsawa village, the forest becomes more intact and hence the community height increased to ca. 30 m of evergreen broad-leaved species. Again in the humid evergreen broad-leaved forest around Lamperi there is an increase of human disturbance (e.g. Wasabi project, National Work Force Camp, and grazing) and the community height shows slight decrease due to gradual sprawling into surrounding forests. Similarly the diameter at breast height and total basal area increased from 17.0 cm, 13.7 m²/ha at 2450 m asl, below Yusipang and 35.5 cm, 15.2 m²/ha at 1520 m asl, at Lobesa, to 87 cm, 66.4 m²/ha at Dochula ridge top indicating low biomass accumulation in the pine forest on both sides of Dochula.

It is clarified that temperature and humidity influences species composition and forest structural attributes (Fig. 5E, F). While soil moisture content shows decisive effect on the forest dimensions (height, diameter, basal area), temperature determines the distribution of species compositions as has been discussed by Wangda & Ohsawa (unpublished) along the similar dry valley slopes of the Bhutan Himalaya.

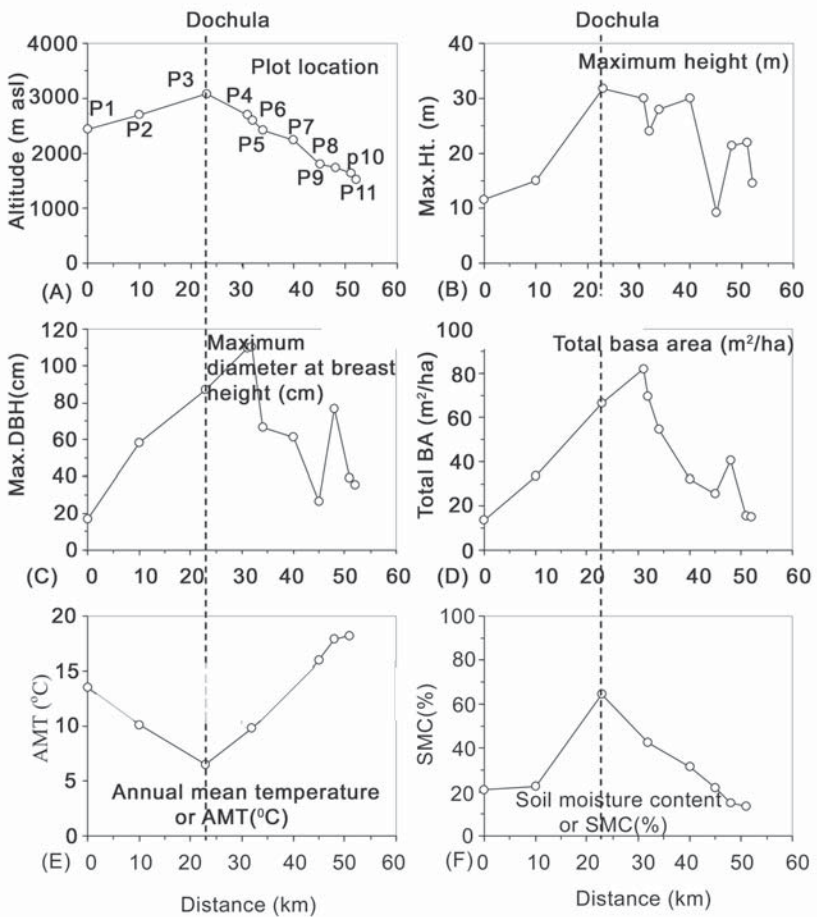


Figure 5. Plot location and forest structural traits with corresponding environmental conditions along the horizontal distance from Semtokha-Dochula-Lobesa series (A) plot location, (B) maximum height, (C) maximum diameter at breast height, (D) total basal area of each forest community, (E) annual mean temperature, and (F) soil moisture content. P refers to sampling plots

Table. 1. Plot details and list of dominant tree species classified according to life form.

Plots	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
Location	BY	AY	DO	LM1	LM	OLM	LU	MD	LB2	LB	LB1
Altitude (m)	2450	2700	3185	2700	2600	2430	2240	1800	1750	1650	1520
SMC %	20.9	22.4	64.4	45.9	42.5	38.0	31.6	22.2	15.7	15.0	13.4
BA (m ² / ha)	13.7	33.3	66.4	82.0	69.4	54.4	31.9	25.5	40.3	36.7	15.2
Max DBH (cm)	17.0	58.0	87.0	110.0	110.3	66.8	61.0	26.5	77	39	35.5
Max Height (m)	11.7	15.0	31.9	30.0	24.0	28.0	30.0	9.2	21.5	23	14.6
Stem Density (/ ha)	4950	2250	2750	1060	2600	3233	3133	6200	5312.5	1300	1600
Species richness	4	9	13	9	10	20	14	13	20	4	7
Shannon's H' (bit)	1.183	0.687	2.628	1.5	2.058	3.112	1.465	2.976	1.7	0.1	0.1
CONIFEROUS TREES	RBA	RBA	RBA	RBA	RBA	RBA	RBA	RBA	RBA	RBA	RBA
<i>Pinus wallichiana</i>	67.0	90.1									
<i>Tsuga dumosa</i>			44.8			21.5					
<i>Pinus roxburghii</i>								5.9	61.0	99.4	98.4
EVERGREEN BROAD-LEAVED TREES											
<i>Quercus lanata</i>	26.4							10.8	12.9		
<i>Rhododendron arboreum</i>	5.9	2.2	4.5			9.4		27.9	16.8		
<i>Quercus semecarpifolia</i>		4.3	15.0			0.0					
<i>Quercus oxyodon</i>				72.3		20.2					
<i>Rhododendron barbatum</i>			3.4			0.0					
<i>Quercus lamellosa</i>					36.9	9.0					
<i>Quercus glauca</i>					24.7	16.4		7.3			
<i>Castanopsis hystrix</i>							69.7	3.6			
<i>Daphniphyllum himalensis</i>							20.0				
<i>Schima wallichii</i>								12.5	0.2	0.1	
<i>Ilex dipyrena</i>				5.2	27.3		0.5				
DECIDUOUS BROAD-LEAVED TREES											
<i>Betula utilis</i>			14.5								
<i>Magnolia campbellii</i>				12.7							

Note: B = below, A = above Y = Yusipang, DO = Dochula, LM = Lamperi, O = opposite, MD = Mendigang, LU = Lumitsawa, LB = Lobesa, RBA = relative basal area.

DISCUSSIONS

Contrasting Vegetation Types and Climatic Conditions on East and West Slopes of Dochula Pass.

The contrasting vegetation and climatic conditions on east and west sides of Dochula is one of the most remarkable characteristics of the dry valley ecosystems in the Bhutan Himalaya (Fig. 6).

Along the same altitudinal range between west slope of Semtokha-Dochula series (ca. 2200-3185 m asl) and east slope of Lumitsawa-Dochula series (2250-3185 m asl) there is a significant difference in terms of climate and vegetation types and this type of contrast on the same topographical gradient is a classic example and can be used for environmental education such as miniature of the vegetation along whole Himalayas including dry west and humid east Himalaya (Fig. 6).

The coldest month mean temperature of -1°C normally used as a thermal indicator for the upper limit of evergreen broad-leaved trees of the East Asian mountains (Ohsawa 1990) occurred at around Dochula (above 3000 m asl) where evergreen broad-leaved *Q. semecarpifolia*, *Ilex dipyrena*, etc still flourish together with *T. dumosa* from both sides. Hence, temperature is still under tolerable range for other evergreen broad-leaved species to flourish around Dochula.

On the lower dry west slope of Wangchu valley *Pinus wallichiana* forest dominates (2200 m asl) which transit into dry *Quercus lanata* and formed the mixed *P. wallichiana*-*Q. lanata* forest (2500-2700) and further transit into the humid *Q. semecarpifolia*-*Picea spinulosa*-*Tsuga dumosa* forest (2800-3000 m asl) around Dochula.

The forest types formed on the east slope of Dochula are totally different from the west slope (Fig. 6). Ohsawa (1987 b) also described series of vegetation patterns along the dry valley slopes of Wangchu (2000 m asl) and Punatsangchu valley, including vegetation along the west slopes of Pelela (3500 m asl) to Kurichu valley (570 m asl) towards east slope of Thrumshingla (3900 m asl). However, the present study found that the distinguishing characteristic of the east slope of Dochula is the formation of humid Fagaceae forest between 2200 to ca. 3000 m asl. Temperature conditions are similar but humidity plays a decisive role on the dry west and humid east slope of Dochula (cf. Fig. 2A, B). The altitudinal difference of ca. 1000 m between Wangchu (2200 m asl) and Punatsangchu (1250 m asl) valley could explain a part of the climatic difference of the two aspect of Dochula (Fig. 6). While the altitudinal difference between Wangchu valley to Dochula is ca. 1000 m, it is ca.

2000 m between Bajo to Dochula. Hence clouds are formed on the upper parts of the east slope as a result of moisture laden valley winds from the valley bottom making the area humid for Fagaceae and Lauraceae species. Contrastingly west slope is much drier due to its short range to the mountain top and clouds are usually formed on the ridge top which makes the lower altitudes dry. Thus only cool dry species appeared on the west slope of Dochula.

Phyto-geographically the west slope of Dochula corresponds to west Himalayan vegetation type such as transition from dry *P. wallichiana* to *T. dumosa* and *Q. semecarpifolia* (Stainton 1972) while the east slope of Dochula showed both dry west Himalayan elements (*P. roxburghii*, *Quercus lanata*) at the lower altitudes and humid east Himalayan elements (*Q. oxyodon*, *Q. glauca*, *Q. lamellosa*, *Castanopsis hystrix*) at the mid-altitudes that differentiates the vegetation from west slope of Dochula and from other mountain slopes (Wangda & Ohsawa unpublished) (Fig. 6). Moreover even though it is only about one hour from Thimphu, there are many rare plants found only limited parts of the humid Himalaya in the world such as *Tetracentron sinensis* of monospecific Tetracentraceae family, which is one of the monotypic east Asiatic families of Trochodendrales. *Tetracentron* is an ancient relict angiosperm with no vessel in its trunk and are distributed from central and southwest China up to Burma, Bhutan and Nepal hence this primitive angiosperm deserves to conserve because of its peculiar remnant botanical features. Another one is *Decaisnea insignis*, a species limited to Himalayas and western China. It has attractive foliage and bell-shaped flowers followed by striking blue fruits in autumn. The conservation and management of the interesting forest types and trees of east slope deserves priority since besides diverse forest types, many developmental activities are occurring in the humid evergreen broad-leaved forest around Lamperi (eg. (1) ca. 120 acres of abandoned Wasabi Pilot Project that disturbed soils, reduces diversity, and accelerated soil erosion at the lower site, (2) conifer plantation changes forest ecosystem, reduces soil water content, and reduces diversity, (3) National Work Force Camp depend firewood on the surrounding forest, and (4) now Botanical garden with a plan of collecting over 46 species of Rhododendrons in the same area may reduce the genetic variation). Thus, if we do not check such pressure at present, the forest ecosystems will undergo drastic changes resulting in loss of biodiversity, shortage of water, reduce timber, firewood and importantly loss of traditional practice of grazing land for yaks in winter and cattle in summer which will affect the life of mankind. We recommend basic ecological research before implementation of any developmental activities in such important forest ecosystems in future.

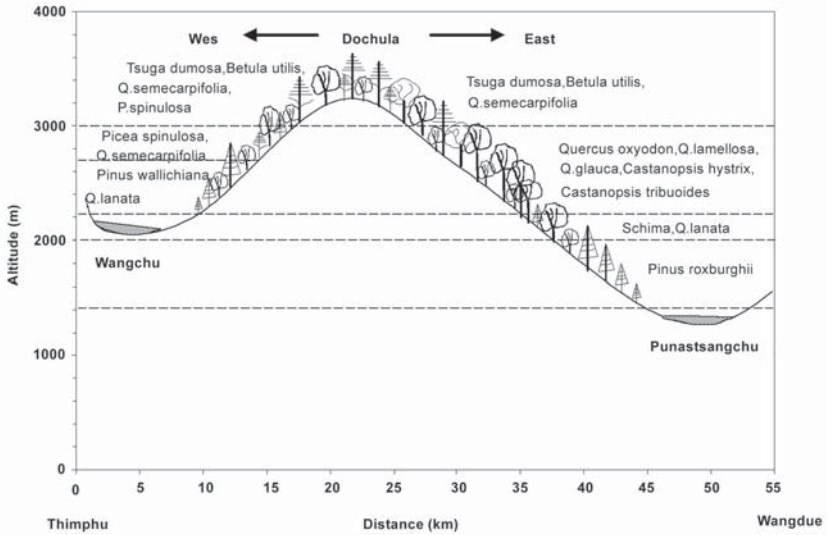


Figure 6: Pattern of vegetation profile with dominant tree species between Wangchu valley from Semtokha through Dochula mountain top to Lobesa, along Punatsangchu valley

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Migratory Cattle Grazing: An Ecosystem Approach To Livelihood

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ABSTRACT

This paper consolidates impact of traditional migratory system of cattle management on their household economy, and describes the interaction between sustainable livestock, forest and pasture resources development. Livestock remain as main livelihood source contributing 71% and 84% of the gross household incomes of herders from Haa and Merak respectively. Seasonal movement of livestock is in direct response to cold temperatures, acute shortage of green forages and income opportunities. In dry valleys, transhumance often makes best sustained use of grassland resources. Mutual understanding regulates grazing between the upstream and downstream cattle owners. The sustained use of grazing resource requires accommodation of traditional rights and clarity on ownership and management of rangeland in the existing legislations. Temperate and sub-tropical rangelands and forest along migratory cattle routes exhibit signs and symptoms of over-grazing. Rangeland management should be based on availability of forage resources, ecosystems stability and an ability to control livestock numbers. Rest periods and rotational grazing are essential particularly in severely depleted ranges to suppress the growth of unpalatable species.

KEY WORDS: Migratory herders, rangeland, ecosystem approach, livestock, pasture development

INTRODUCTION

High elevation herders have been practicing migratory cattle grazing as forest dependent livelihood strategy from temperate to sub-tropics of Bhutan for more than 1300 years. Mongar and Gyeltshen (2001) emphasizes highlands ranging from 3500-5000m elevations as an indispensable land use system for alleviating rural economy through rearing of livestock. However, little is understood with regard to migratory cattle and its impact on the household subsistence economy.

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The Land Act 1979 and Forest and Nature Conservation Act 1995 devolve grazing rights over grasslands to communities but lacks provision to clarify its ownership and management. This restrictive provision has resulted in the ownership conflicts and resource use constraints (Ura, 2001). It has further dissuaded the herders in improving the grasslands (Norbu and Dorji, 2001). The complexity of dual and multiple ownership of rangeland based on temporal separation (herders in winter and somebody else in summer), absentee ownership of grazing rights, inadequate consideration on social and geographical factors have impeded the of the draft pasture policy (MoA, 2001).

Information on factors responsible for seasonal movement of migratory herds and mechanisms that cements relationship between upstream herders and downstream communities/individuals are limited. Mongar and Gyeltshen (2001) suggest that such tradition have symbiotic relationship between individuals who do not have grassland but own livestock to graze and vice-versa. Wangchuck (2003) provides an example of similar tenure system in Laya where the monasteries own grazing rights over grasslands and people of Laya compensates in-kind for grazing the pastures. However, he argues that such practice neither encourages investment in the development of pastures nor facilitates equitable and sustainable use of forest and pastures.

Livestock grazing as a cause for forest degradation has been debated (MoA, 2001). Wangchuck (2003) states that when large number of herds grazes over a long period of time or reduces the grazing intervals, impact becomes evident by proliferation of unpalatable trees and shrubs. Therefore, regulating forest grazing in high cattle density areas were suggested. Conversely, cattle's grazing in the forest was considered to be environment-friendly as the nutrients lost from soils are replenished through dung and urines (DALSS, 2002). It was also indicated as a mechanism to optimize the use of available forage resources for the development of small and viable livestock growing enterprises. This paper consolidates the impact of migratory cattle on herder's subsistence economy, forest regeneration and mechanisms underpinning seasonal movement between the upstream herders and downstream communities/individuals for sustainable and equitable livestock, forest and pasture resources development.

MATERIALS AND METHODS

Trans-altitudinal ecosystem walk and talk approaches were undertaken en-route Haa to Samtse district and Merak to Phongme/Radhi villages located in the extreme western and eastern region of Bhutan, respectively (fig.1). About 30 herders from these sites were interviewed in their make-shift camps using semi-structured questionnaire. Data collected include demography, household incomes, migratory

routes, constraints and opportunities, factors responsible for seasonal movement and mechanism that regulates grazing. The traditional migratory routes were mapped using global positioning system and digital snapshots of sites taken to document evidences. Temporary plots of 100m² were laid out along the migratory routes to assess impact on regeneration. Secondary data and information were referred to fill in gaps and substantiate limitations.

Haa is located between longitude 89°17' east and latitude 27°23' north in the western Bhutan (Rinchen and Pushparajah, 1994) and Merak between longitude 27°18' north and latitude 91°52' east in the eastern Bhutan (fig. 1). Haa has a population of 8453 averaging 6.5 persons per household (Rinchen and Pushparajah, 1994). Herders originate mainly from Uesu and Sama sub-district constituting 71% population of the whole district. About 97% of the district is forested. Economy is subsistence-oriented and depends on livestock, vegetables, cereals and cash crops.

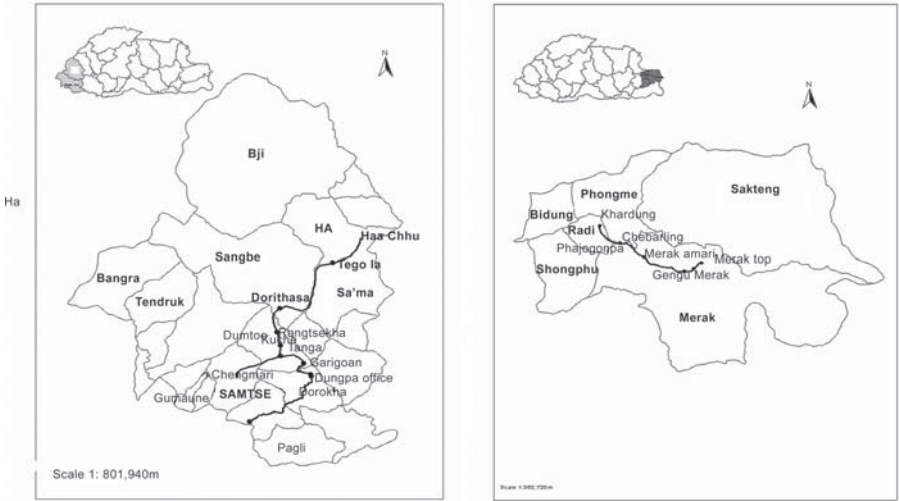


Figure 1: Study sites showing migratory cattle pathways enroute Haa to Samtse and Merak to Radhi, Trashigang District.

Merak constitutes; Merak, Gengu, Khashiden and Khiliphu hamlets with a gross population of 2005 from 260 conglomerated households. It has a geographical area of 8677km² and falls under the administrative jurisdiction.

The area also a part of Sakten wildlife sanctuary and endowed with pristine fir, mixed conifers and temperate broadleaf forest interspersed with rich repository of natural rhododendrons (NCD, 2004). The residents depend on livestock husbandry as main source of livelihood. In recent years, Merak farmers have also started to grow agricultural crops like potatoes in their home gardens.

RESULTS AND DISCUSSION

Migratory Cattle Grazing Strategy

Cattle is the mainstay of herders economy contributing 71% followed by horses 20%, cash crops 8% and vegetable 1% in Haa and similarly 84% followed by sheep 15% and horses 1% of the gross annual household incomes in Merak (fig.2).

Cattle migration from temperate to sub-tropics of Bhutan is in direct response to local environment, acute shortage of green forage resources and livelihood and income opportunities. Downstream migration from Haa commences during October when temperature drops to 4°C and returns during March as temperature rises to 12.9°C. About six herds migrates to Chengmari in Nainital under Samtse and 50 herds towards Torsa, Phuentsholing under Chukka district as winter destinations following these routes and stopovers (fig.1). Merak cattle migrate during November and graze in Chebarling, Kangpara and far south to Shingkhari Lauri and returns by April/May with the onset of summer.

Large proportion of the migratory herds comprised local cattle with 64% and 55% in case of Haa and Merak respectively. There are virtually little improved and natural pastures available for foraging by these cattle especially during the severe winter months. Herder's re-iterates shortage of forage resources and grazing lands as severe limitations to improving livestock health and productivity. Fodder production through introduction and expansion of pastures and crop diversification is also constrained by limited agricultural land and extreme temperatures. Such prevailing condition forces herders to migrate their cattle to downstream forest and grasslands endowed with luxuriant grass growth and tree fodders.

Livelihood and income opportunities in lowlands further influences seasonal movement of livestock. The productivity of agricultural crops like paddy, maize and orange stands at 4.1t/ha, 3.2t/ha, 8.8t/ha in warm humid sub-tropics of Samtse compared to 0.56t/ha, 0.38t/ha, 0.38t/ha in temperate regions of Haa (fig.3). This low productivity of cereals and cash crops forces herders to substitute cheese and butter with food and non-food household consumer items from lowland communities and individuals. Literally cut-off by roads and market infrastructures, Haa's horses and mules serve as engines of transport for Dorokha's oranges and cardamom to downstream market outlets. Horses and mules carry about four to seven pons (a pon is a measure of weight which equals 80 oranges) of mandarin at a time depending on their sizes. The number of days transported are not accounted for and carriers are paid a carrying charge of Nu.85 to Nu.90 per pon delivered. A herder owning about six horses earns a gross income of over Nu.60, 000 in a single harvest season lasting from December to February. Apart from cash crops, mules

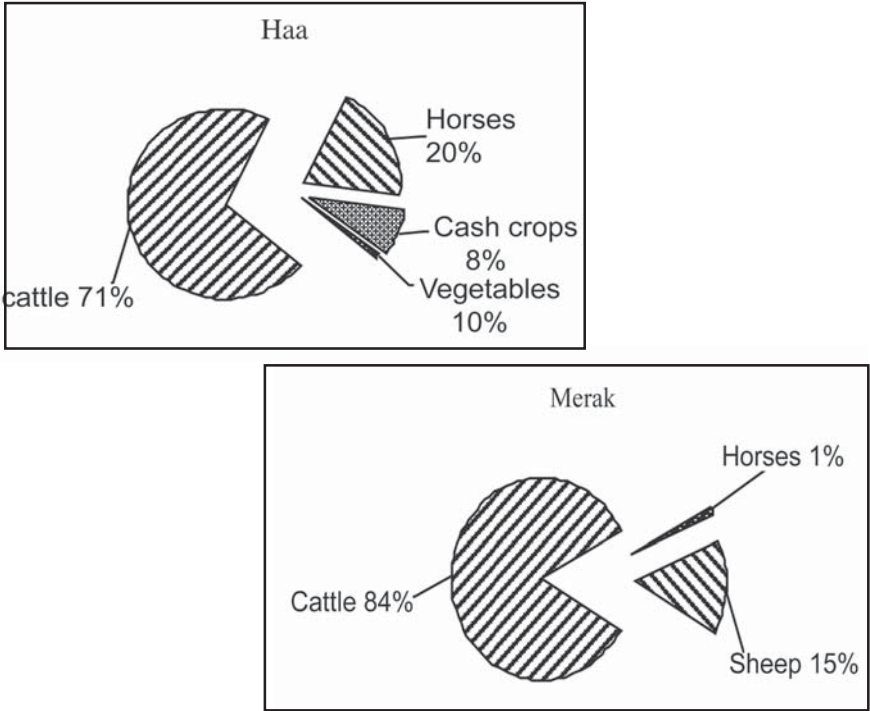


Figure 2: Contribution of cattle products to household economy Income from products like cheese and butter are used for buying and/or bartering basic livelihood necessities from downstream individuals and communities in order to sustain household food security and self-sufficiency for a year or even years.

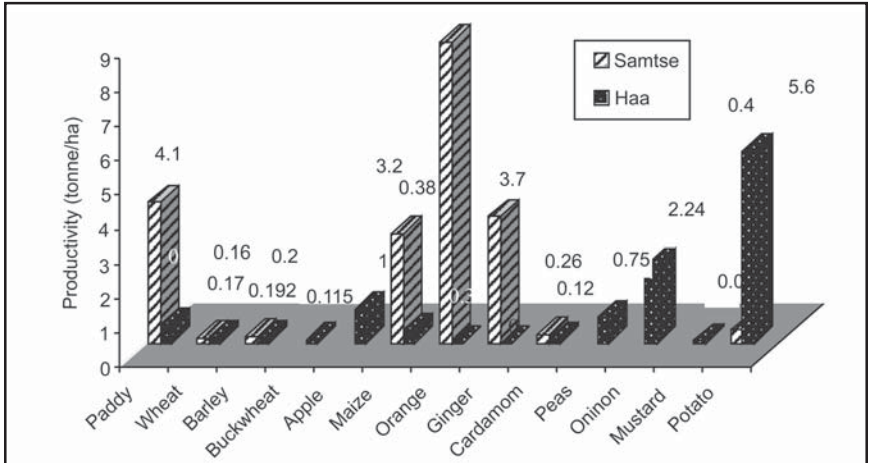


Figure 3: Comparison of productivity of major agricultural crops

and horses are also engaged in transporting construction materials for government infrastructures and food rations for schools. Most of the stocking of food, cloths and consumer items are transported during the winter months and herders does most of the work. Similarly, Merak produces 15 and 29 metric tonnes of butter and cheese compared to 1.8 and 3.6 metric tonnes in Radhi (fig.4). The surplus production of 75% butter and 80% cheese (fig.5) therefore have to be necessarily marketed and/or bartered with livelihood necessities from downstream urban centres like Trashigang. Low consumption within Merak is justified by population of 2005 persons from the whole sub-district compared to 2124 in Radhi hamlet alone. These strategies have evolved into a symbiotic relationship from age-old times as an ecosystem approach to securing herders livelihood.

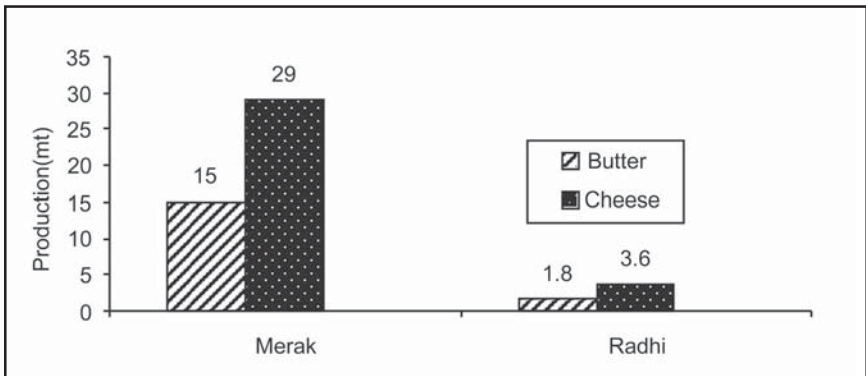


Figure 4: Comparison of butter and cheese production

Traditional lifestyles of herders have remained unchanged as accesses to outside world are cut-off by road and market infrastructures. Agriculture extension staffs state that development interventions introduced to result gradual changes in their nomadic lifestyle have become counter-productive. For example, in Merak herders have switched back to traditional open-earth stoves dismissing firewood efficient bhukaries supplied to reduce ill-effects of smoke. Reports from other parts of Bhutan however, indicate that herders of Soiyaksa have switched from herding to a more settled urban lifestyle (Kuensel, 2004). Cattle migration trends from the central Bhutan show gradual decrease in the number of herders migrating (Rinchen, 2004). The declining trends are attributed to shortage of caretakers, adoption of improved cattle breeds and diversification and specialization of agricultural activities. Norbu et al (2003) highlights that with the advent of socio-economic changes, herders have access to health, education and markets in accessible areas and as a result herding has become a secondary job. While these trends may hold true due to planned development interventions in accessible areas, yet many far-flung herders are reluctant to relinquish this traditional way of nomadic life.

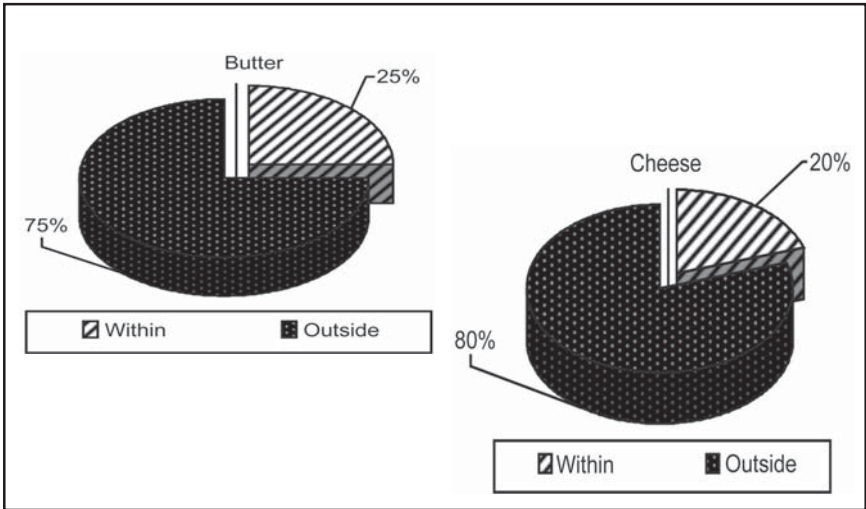


Figure 5: Consumption of butter and cheese within and outside Merak

Grazing Rights and Management of Grasslands

Grazing rights of grassland are either privately or community-owned. Herders with dual land ownership (winter and summer pastures) have exclusive grazing rights. Those who do not own grazing land have *usufruct* over community grasslands and forest areas traditionally set aside for grazing. Often herder with large number of cattle compensates the downstream communities/individuals on-kind and equity basis depending on months/days required to be grazed in a season. When cattle migrate upward, these lowland grasslands and forest are allowed to be grazed by sedentary cattle. The cattle owners reciprocate with maintenance works such as protection of naturally grown/planted fodder seedlings.

In Merak, large tracts of natural grassland are fenced using stones and dead trees and branches allowing grasses to regenerate and protect against grazing by cattle belonging to others. Herders rotate cattle within and between grasslands as strategy for optimum utilization of resources. Gyamtsho (1996) points out rotation of migratory yak herds by Dhur residents of Bumthang as meticulously planned between pastures based on years of experience and calculating even the number of days required for grazing. Similarly Ura (2002) exemplifies allocation of grazing areas within grassland to optimise stocking rates and pasture productivity. Spatial regulation of cattle provides a reasonable time lag for forage resources to regenerate and restock the grazed areas. Thus good results may be expected from rotational grazing that allows every part of the pastures to grow into maturity at least once in

few years by simply reducing the herd's size or closing some part of pastures during its initial growing season. The seasonal movement of cattle between winter and summer pastures is largely in harmony with growth and availability of forage resources. For example, in Merak, migratory month starts with July for summer, August for autumn and September for winter pastures attuned to fodder growth and availability.

Impact on Forest and Grassland

Migratory herds browses virtually days and nights in the course of movement en-route high to low elevations. The forest vegetation along the routes exhibit signs and symptoms of heavy browsing, trampling and degradation exacerbated by fire and unknown environmental factors. Opened up forest patches are not uncommon at frequent intervals along the established routes. At 3,000m and above, Rhododendron seedlings out number prime timber species of fir and junipers in seedling classes (about 6767 seedlings/ha of former with 4033 & 2767 each of latter). This may be due to excessive grazing by yaks. Yaks are voracious herbivores adapted to high elevation climate and virtually gain access to most sites except inaccessible rocky and precipitous terrains. Gyaltshe and Dorji (1998) reports that yaks are highly adapted to grazing short grasses and thus reduce the carrying capacities of most grazed alpine grasslands. Gyaltshe and Bhattacharya (2003b) estimates 47% higher biomass production with increase in nutrient content of ash, crude protein and calcium in un-grazed natural pastures compared to the grazed sites. These differences are attributed to intensive grazing by yak, cattle and horses including wild blue sheep (*Pseudois nayaur*). According to Gyamtsho (1996) most alpine grasslands are over-grazed with a grazing pressure varying from high in Laya and Lingshi to moderate in Lunana with a mean grazing pressure of 5.6ha per YAE (Adult Yak Equivalent). He further states that not only yak but also large flocks of blue sheep (>200 animals per herd) competes grazing of palatable grasses and as a result unpalatable plants like Rhododendron, *Rumex nepalensis*, poisonous *Senecio* and *Ligularia* colonizes the grazed sites. Wangchuck (1995) observed dietary overlap between the yak and blue sheep. The plant communities significantly grazed by both animals included *Cyprus*, *Carex*, *Bistorta macrophylla*, *Schoenoplectus*, and *Potentiallia microphylla*.

As the cattle migrate downward, temperate mixed hardwood forest and grasslands come under immense pressure. Unpalatable and non-commercial species like *Daphne*, *Symplocos*, *Cinamomum*, *Viburnum*, *Eurya*, *Ilex*, *Litsea*, *Rhododendron* and *Bamboo* colonizes the heavily grazed sites (Rinchen, 2004; Davidson et al., 1999). The forest and fodder trees are also thinned from beneath by lopping and de-branching by herders. The grassland and forest in the winter grazing sites for

Merak livestock are overgrazed and result in soil erosion and landslides. As the migratory cattle moves further traversing lowland sub-tropical forest and settlements, sedentary cattle suffers from outbreak of Foot and Mouth Disease (FMD) causing morbidity and mortality. FMD outbreak is reportedly attributed to untimely vaccination of migratory herds and transport of meat products from high to low elevations and vice-versa. The practices of “ring vaccination” are some preventive measure of the disease.

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Physical Characterization of Bhutanese Yak

Tashi Dorji¹ and Gyem Tshering¹

ABSTRACT

The aim of this study was to compare biometrical measurements, describe coat colour and horning pattern of yak population from three regions of Bhutan (west, central and east). The measurements including heart girth, body length, wither height and estimated body weights are larger for yak from western Bhutan. The eastern Bhutan yaks are the smallest. Black coat colour yak was most frequent with 60 to 73% occurrence. The differences in body dimension, coat colour, horning pattern and woolliness suggest that eastern Bhutan yaks are distinct to those from other two populations. These results are important for designing yak breeding and conservation programmes.

KEY WORDS: yak, phenotype, colour, body size, Bhutan

INTRODUCTION

Earlier reports on Bhutanese yak stated wide differences in terms of body size and physical appearance including coat colour, hair type and horning characteristics (Tshering and Acharaya, 1996; Tshering and Dorji, 1997). However, these studies were based on general observations made in a few locations. There is very limited recorded data on phenotypic variation across yak populations in Bhutan.

Knowledge on outward appearances of yak can be a valuable tool as breed descriptors (FAO, 1997). For example, Pal (1993), based on morphological appearances, characterized Arunachal Pradesh (North East India) yaks into four types; *Common type*, *Bisonian type*, *Bare Back type* and *Hairy Forehead type*. Physical attributes can complement and form a part of cytological, blood group and molecular procedures to categorise yak into definite breeds or strains (Nivsarker *et al.*, 1997).

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Traits such as coat colour and horning pattern may not have economic importance. However, nomadic communities attach high value to specific colour and horning patterns. High aesthetic values for coat colour, such as white, fetch the farmers a premium price at the barter table (Joshi, 1982).

Therefore, the objectives of this study are:

- To compare biometrical measurements among the three yak populations (west, central and east) of Bhutan;
- To describe coat colour variations, horning patterns and other physical attributes of yak in the study area.

MATERIALS AND METHODS

Visits were made to yak herds at several locations across the yak rearing districts in the country (Table 1). Physical measurements were taken using ordinary measuring tape. Observations on coat colour and other physical differences were recorded.

In total, 109 adult animals (>6 years old) of both sexes were measured. Young animals were excluded due to difficulty in handling. An additional 836 animals were recorded for coat colour and horning characteristics.

Selected body parameters measured are height at wither, body length, heart girth, height at hips and cannon circumference. Body weights of animals were estimated from the linear dimensions using methods of Li and Wiener (1995):

Body weight (kg) = (heart girth)² X body length X 70, where body length and heart girth are in metres.

Coat colour variation and horning pattern (horned or polled) were observed in herds and along trekking paths. These observations were noted separately in a field book through out the field trip. Classification of coat colour was largely based on Namikawa *et al.* (1988) and Pal (1994b):

- Black; includes animals with brown coat on the head, back or belly parts;
- Black and white patches; includes animals with dorso-ventral white line, piebald features and white tail switch;
- Brown; includes animals with black or white pigmentation on the forehead, withers, legs and tail switch;
- White; includes animals with completely white colour, plus albino;
- Roan; includes animals which show a typical bluish tint in body coat.

Table 1: Study locations for description of yak phenotype

Region	Districts	Study Locations
West	Haa Paro Thimphu Gasa	Komla, Damthang Soey Yaktsa, Nubri Naro, Dagala Laya, Lunana
Central	Bumthang Wangduephodrang	Dhur, Chokortoe, Ura, Shinkhar Sephu, Phobjikha
East	Tashigang	Merak and Sakten

RESULTS

Body Measurements

In Table 2 are summarised the measurements of yak from different regions of Bhutan. The body dimensions of both the sexes were larger for western region yak, compared to those from the central and eastern regions. The central region yak show physical parameters that are intermediate between the values of the other two populations. Pronounced sexual dimorphism was noticeable, with males being larger than females.

Table 2: Average body measurements of adult yak in three regions of Bhutan

Trait	Western Region		Central Region		Eastern Region	
	M(n=31)	F(n=32)	M(n=9)	F(n=19)	M(n=6)	F(n=12)
Height at withers (cm)	136	117	129	110	128	113
	<i>1.2</i>	<i>0.8</i>	<i>1.9</i>	<i>5.8</i>	<i>2</i>	<i>1.6</i>
Body length (cm)	159	137	152	133	148	133
	<i>1.7</i>	<i>1.2</i>	<i>4</i>	<i>1.2</i>	<i>1.7</i>	<i>2.3</i>
Chest girth (cm)	194	165	185	165	177	160
	<i>1.7</i>	<i>0.9</i>	<i>3.5</i>	<i>1.3</i>	<i>2.8</i>	<i>1.6</i>
Body weight (kg)*	419	264	369	252	323	239
	<i>11</i>	<i>4</i>	<i>22</i>	<i>4.5</i>	<i>12</i>	<i>8</i>
Height at hips (cm)	107	97	101	91	101	93
	<i>0.9</i>	<i>2.2</i>	<i>1.8</i>	<i>0.9</i>	<i>1.2</i>	<i>1.7</i>
Cannon circumference (cm)	21	17	20	16	19	16
	<i>0.2</i>	<i>0.3</i>	<i>0.2</i>	<i>0.2</i>	<i>0.2</i>	<i>0.2</i>

M-Male, F-Female, n-Number of animals, *Body weight (kg) = (Chest girth, m)²x (Body length, m) x 70. Figures in the italics are standard errors

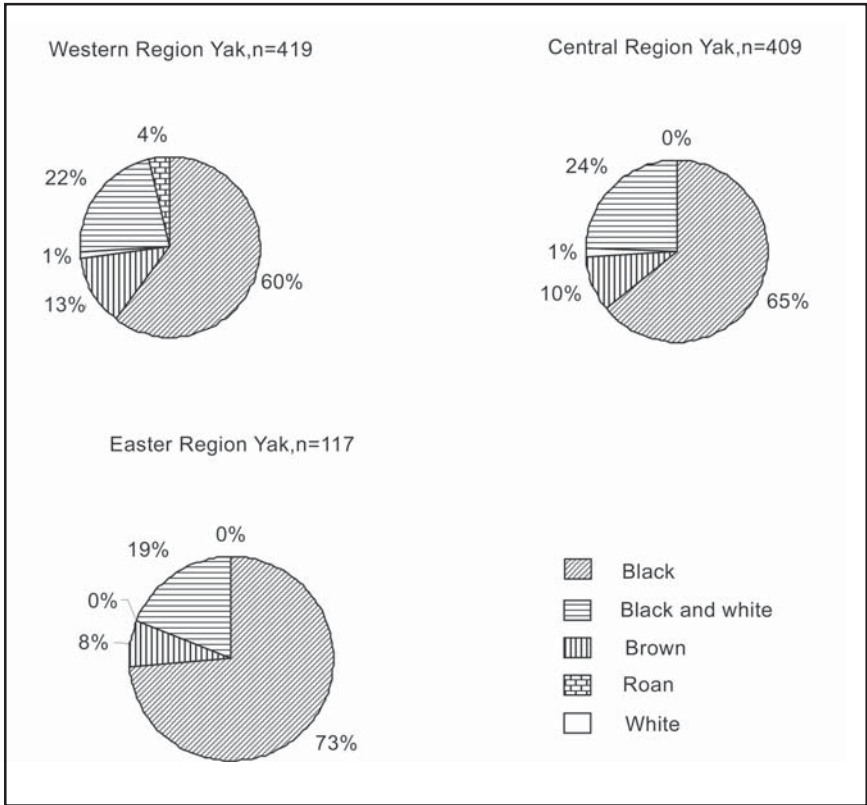


Figure 1: Coat colour variation in Bhutanese yak populations (n-Number of animals)

Coat Colour Variations

The colour patterns observed among Bhutanese yak are presented in Fig. 1. Black colour was the most common followed by a mixture of black and white shades. Absolute white or albino animals were the least frequent. Black yak comprised 73 percent, 65 percent and 60 percent in eastern, central and western region populations, respectively. About 4 percent of western Bhutan yak had typical bluish tint appearance of roan. This was not observed in the other two populations. In addition, no albino animals were noted among the east Bhutan yak.

Horning Patterns

About 9 percent of the yaks observed in the survey area were polled (Table 3). The proportion of polled yak was higher in eastern Bhutan, compared to the western and central populations.

Table 3: *Horning characteristics of yak in three regions of Bhutan*

Population	N	Proportion of polled yak (%)
Western Region	419	10
Central Region	409	7
Eastern Region	117	17
Total	945	9
N-number of animals		

DISCUSSION

Variation in Body Measurements among Three Yak Populations

The linear dimensions including withers, body length, heart girth and body weight are parameters that are reasonably accurate. However, some of these are influenced by seasonal variation. Li and Wiener (1995) reported that heart girth, affected by body condition, showed a reduction in size at the end of the winter period while height at withers was not affected. Yak also loses approximately 25 percent of body weight during winter (Li and Wiener, 1995). Measurements on yak in the present study were obtained during winter period, so the seasonal influence should be taken into account.

The body measurements indicated that yak from western Bhutan is larger than those from the central and eastern population. Large variation in the phenotypes, body size and linear proportions can occur due to inherent genetic differences, environment (micro climate, feed and fodder resources, management variables) or interactions of all these factors.

Some of these differences may be attributed to genetic history. In addition, Gyamtsho (1996) emphasised the availability of adequate grazing resources as an important cause for the differences in body size among yak in different regions.

Nomadic communities reinforce this statement, stating those yaks are larger in areas where an alpine environment favours the growth of *yartsa guenbub*

(*Codyceps sinensis*). Perhaps the growth of this plant species may be associated with optimum conditions for other nutritious pasture. However, very little has been described about the rangeland ecology in different yak herding zones of Bhutan and it is difficult to assert this explanation. In other countries, Nivsarker *et al.* (1997) correlated change in body dimensions and character of yak with ecological conditions. For example, large yak from Qinghai province of China were associated with the abundance of greener pastures in these areas.

Herders' breeding practices can lead to differences in phenotypic traits. The western Bhutan's yak owners practice pure line breeding. This region has a high proportion of purebred yak, giving a wide population base for selecting better breeding bulls. Geographically, western Bhutan pastoralists are also in a better position to allow for exchange of breeding bulls between their herds. This may have provided opportunities to mitigate local inbreeding and increase selection intensity. In central and east Bhutan, cross breeding with cattle reduces the availability of purebred yak and limits selection option. The herders in central region frequently obtain yak bulls from their western counterparts. This might explain the intermediate position in physical measurements between the western and the eastern population.

An account of the management factor influencing body size was reported among yak in the Russian Federation Territories (Sarbagishev *et al.*, 1989). Yak in Kirgizia are substantially larger than those of Tajikistan. The reason given was that yak of Kirgizia were not milked and were bred only for meat. This ensured more milk for the calves, which leads to better growth and body size. However, this may not apply in the Bhutanese situation, as there is little difference in milking regimes for yak across the country (Gyamtscho, 1996).

In general, the body parameters of Bhutanese yak are comparable to those reported for some recognised Chinese yak breeds (Li and Wiener 1995). The western Bhutan yak population show similar body dimensions to that of Maiwa and Alpine Tibetan Yak, while eastern region yak show body measurements similar to Gannan yak from Gansu province of China. How they are related at the genetic level remains to be investigated.

Coat Colour Variation in Bhutanese Yak

The predominantly black coat colour observed in Bhutanese yak is consistent with observations among yak breeds in other countries. Bat-Erdene (1996) reported 68 percent black colour among 64,000 Mongolian yaks observed. Similarly, about 65 percent of Nepalese yak are reported to have the black coat colour (Namikawa *et al.*, 1992). Many authors attribute the prevalence of black in yak colour to the

herders' preferences. Yak owners like a herd of uniformly black coloured animals, which may lead to selection for this colour (Nivsarker *et al.*, 1997).

With regard to Bhutan, Gyamtsho (1996) stated the preference of yak herders from Laya in western Bhutan for a black coat bull with white tail. Herders suggest black animals are less prone to skin lesions. In the same context, Li and Wiener (1995) reported predominantly dark coat colours of yak to be a natural adaptation to protect against the effects of solar radiation at high altitudes.

Alpine dwellers from east Bhutan view the matter differently. Folklore states that when their ancestors migrated from Tibet in the 7th century, a big lake had to be crossed. Black coat yak were able to swim across the lake and travel with them while the white ones could not, hence accounting for the dominance of black coloured animals in their herd.

A mixture of black and white coat animals ranked second highest amongst Bhutanese yak. Such animals include those with piebald feature, mostly with a white dorso-ventral line. In other studies such colouration was also termed as "spotty black" (Bat-Erdene, 1996), "grey hair line" (Nivsarker *et al.*, 1997) and "Hereford like" (Namikawa *et al.*, 1992). Pal (1994b) noted that 40 percent of Indian yak were of a black and white patched colour.

White or albino was the most rare colour variant among Bhutanese yak. Only one percent of yak observed in west and central Bhutan were white, while the colour was absent from eastern Bhutan's population. Interestingly, a herder from upper Chokor valley in central Bhutan believes that white yak bulls often emerge from mountain lakes and sire their female yak. Such bulls in their language are called *Tsholang*. Its progenies are considered as gifts from their local deities and are highly valued. Herders associate occurrence of such events with bringing of good fertility among their yak and fewer health problems in the herd. The residents of Naro village in western Bhutan provided similar account of rare white bulls originating from mountain lakes. Pure white yak are also reported to be rare in Nepal and they are highly prized (Joshi, 1982).

Phillips *et al.* (1946) suggested that the diversity of colours seen in domestic yak might be due to crossing with cattle in earlier periods of domestication. A variety of colour combinations including golden brown, ash, grey and white were reported in yak from some parts of Tibet, where crossing with cattle is unavoidable (Nivsarker *et al.*, 1997). Such diverse colour range, especially the white type, has not been observed among wild yak (Li and Wiener, 1995).

Gupta and Kumar (1994) state that coat colour in yak has no relation to the productivity of the animal. However, Bat-Erdene (1996) argued colour to be

associated with the adaptation and productive performance. His research showed that live weight loss of white yak in winter was 20 percent of the summer weight while black yak lost only 15 percent. Also, white yak frequently suffered from ocular disease and sunburns. It indicated that black coloured animals were adapted to their natural environment and, consequently, were more productive. In cattle, Holstein cows with higher percentage of white colour are reported to show lower depression in milk yield and reproductive traits in the regions of higher solar radiation (Hansen, 1990). This is due to its lowered absorption of solar radiation that results in reduced heat stress (Olson, 1999).

Horning Characteristics

Differences in horning characteristics were also apparent among Bhutanese yak. The proportion of polled yak in east Bhutan (17 percent) was higher, compared to <10 percent hornless yak in the other two regions. A photograph of polled yak is shown in Fig. 4.3. Polled yak are referred to as *Gulum* in some parts of west Bhutan and as *Ayu* or *Ayum* in the east. However, pastoral communities do not believe hornless animals to be a different breed or type; neither have they mentioned any special characteristics in terms of productivity. But herders do report more aggressive behaviour in polled yak compared to their horned counterpart.

In Tibet, the proportion of polled yak was reported to vary from one to 17 percent. However, in Gansu province of China, polled bulls were selected for breeding and the proportion of such animals was as high as 80 percent (Li and Wiener, 1995). Similarly, in Mongolia, polled yak are preferred for easy handling. Bat-Erdene (1996) reported that 84 percent (out of 64,000 Mongolian yaks observed) were without horn. In India, about 10-12 percent of yaks are hornless (Pal, 1993) but there is no selection for horning character (Nivsarker *et al.*, 1997). In Nepal, hornless yak are not valued and polled bulls are castrated for use as riding animal (Joshi, 1982).

Other Descriptive Characters

In addition to the phenotypic variants described earlier, the hairy forehead type reported for the Arunachal yak (Pal *et al.*, 1994a) was frequently observed among the eastern Bhutan yak population. Such animals possess thick glossy hair, which covers face, forehead and eyes. Similar physical features are reportedly common among yak in Qinghai province of China (Pelieu, 1984).

Eastern Bhutan yak population typically bears longer body wool immediately behind the base of horns, ears and extending to neck. Such characteristic wooliness rarely occurs amongst western or central Bhutan yak.

CONCLUSION

The results show that there are wide variations in the phenotypic characteristics of Bhutanese yak. Selected physical measurements including heart girth, body length, wither height and body weights are larger for yak from western Bhutan. The eastern Bhutan yaks are the smallest. Although physical characteristics like colour pattern and horning are of less economic importance in a pastoral community these traits can assume significance. High frequency of black colour yak can be linked to the herdsmen's preference.

Differences in body dimension, coat colour, horning pattern and woolliness suggest that eastern Bhutan yak is distinct to those from other two populations. These results shall provide valuable input for designing yak breeding and conservation programmes.

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In Search of Species Suitable For Temperate Pasture Mixtures in Bhutan

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ABSTRACT

Farmers in temperate areas were recommended to use mixtures containing white clover; Italian ryegrass, tall fescue and cocksfoot. Strong dominance of white clover in fields seeded with these mixtures induced the search for alternative species or establishment methods. Two experiments were conducted across a range of temperate environments from 1996-2002 to evaluate grass-legume mixtures for species composition and dry matter yield and the effect of seed rates on contribution of species to the total species composition. Except for Khangkhu the dry matter yield was not affected by the mixture components and the seed rates of tall fescue, cocksfoot and Italian ryegrass. The dry matter yield of lotus mixture was comparatively lower than white clover and lucerne mixtures. Lucerne mixture yielded higher at Khangkhu. Seed rates of grass species did not affect the frequencies of individual species. Cocksfoot frequency increased consistently over 6 years and cocksfoot affected the frequency of tall fescue. The frequency of lucerne, Prairie grass and Dallis grass increased at Khangkhu while the persistence of these species was poor in grass-legume mixtures at Bathpalathang.

The current extension recommendations need to be revised taking into consideration the strong competition by cocksfoot and variations in dry matter yield and species composition of mixtures between locations. It is proposed that specific mixtures should be identified for specific locations.

KEYWORDS: Mixture, dry matter yield, frequency, seed rate, cocksfoot, tall fescue, white clover.

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INTRODUCTION

In Bhutan perennial fodder species are generally grown in mixtures comprising grass and legume species. Grass and legume mixtures commonly form a major and important source of fodder owing to a greater total herbage yield from grass and legume associations where N fertilizers are not applied. Compared to a system based on grass plus fertilizer nitrogen, a grass-legume mixture is more efficient in terms of the total amount of energy used in a grassland system (Pearson and Ison 1997). The reduced weed encroachment and soil erosion in grass-legume mixtures provide greater stand longevity than legume or grass monocultures (Droslom and Smith 1976). However, species and cultivars in a mixture have to be compatible with each other and need to have similar requirements for management and environment. The evaluation of germplasm materials therefore has to test the compatibility of potential species/varieties in mixtures with the target partners.

Research activities in the 1970s resulted in the development of a package of practices for fodder resource development in the temperate areas of Bhutan. The main component of this package was the recommendation of a mixture containing white clover (*Trifolium repens*), Italian ryegrass (*Lolium multiflorum*), tall Fescue (*Festuca arundinaceae*) and cocksfoot (*Dactylis glomerata*) (Roder et al., 2001). Experiences with temperate mixtures in Bhutan were reviewed by Roder et al. (1997) and recommendations for establishment and fertilizer application were also discussed. The review by Roder et. al. (1997) concluded that (i) white clover, cocksfoot, tall fescue, and under specific conditions Italian ryegrass have proven to be well suited for most temperate areas of Bhutan (ii) the poor results obtained with perennial ryegrass, meadow fescue (*Festuca pratensis*) and common meadow grass suggest that these species are not suited for Bhutan and (iii) rather than testing additional species or conducting further studies with species already discarded in the seventies, it would be more important to conduct variety trials with the selected species especially for cocksfoot and tall fescue.

Out of all the grasses tested in the 1970s and early 1980s, only cocksfoot secured a significant proportion in species composition in grass-legume mixtures. The high contribution of white clover to the total dry matter was frequently seen as a disadvantage because of bloat, the need for frequent cutting/grazing, the high P-requirement and the limited drought tolerance (Roder, 1996).

This paper reports the results of two multi-location studies carried out on grass-legume mixtures from 1996 to 2002. The objectives were to compare mixtures containing lotus (*lotus pedunculatus*), lucerne (*Medicago sativa*), red fescue (*Festuca rubra*), perennial ryegrass, foxtail meadow (*Alopecurus pratensis*), awnless brome (*Bromus inermis*), Prairie grass (*Bromus catharticus*), Dallis grass (*Paspalum dilatatum*), and common meadow grass (*Poa pratensis*) with the mixture presently recommended and evaluate the effect of seed rates on species composition.

MATERIALS AND METHODS

Experimental Site, Design and Treatments

Two experiments were conducted from 1996 to 2002. The recommended mixture consisting of white clover, cocksfoot, tall fescue and Italian ryegrass was used as control for both the experiments. On-station trials were replicated using Randomized Complete Block designs while single plots were used for on-farm trials. The description of individual sites for Experiment 1 and 2 is presented in Table 1 and 2.

In Experiment 1 the additional species used were perennial ryegrass, foxtail meadow, awnless brome, red fescue, common meadow and lotus (Table 3). The mixtures were tested in replicated trials at Batbalathang and in single plot trials at six on-farm locations. The on-station trial consisted of four replicates and an individual plot size for on-station and on-farm trials was 50m². A gap of 50cm was maintained between plots and 1m between replicates. Besides new grass species, attempts were made to influence the grass and clover balance as well as the grass species composition through variations in the seed rate of white clover, cocksfoot and tall fescue.

In Experiment 2 the additional species included were Prairie grass, Dallis grass and lucerne (Table 4). Mixtures were tested in replicated trials at Bathpalathang (Bumthang), Yusipang (Thimphu) and Khangkhu (Paro) and the individual plot size was 9.25m². A gap of 50cm was maintained between plots and 70cm between replicates. Unlike Experiment 1, cocksfoot was not included in mixtures other than the recommended mixture. This was intended to assess the contribution of tall fescue to the total species composition in absence of cocksfoot.

Table 1: Description of individual locations for Experiment 1

Location	Elevation	Rainfall (average 1997-99)	Land type	Sowing date
Batbalathang	2650m	842mm	Kamzhing	12/7/96
Dhur	3100m	230mm	Pangzhing	18/7/96
Chumey	2900m	400mm	Kamzhing	17/6/96
Thimphu	2350m	673 mm	Kamzhing	13/6/96
Haa	2800m	1003 mm	Kamzhing	5/8/96
Chukha	2100m	1714 mm	Kamzhing	21/6/96
Paro	2300m	1226 mm	Kamzhing	7/6/96

Table 2: Description of individual locations for Experiment 2

Location	Elevation	Rainfall (average 1999-2002)	Land type	Sowing date
Batbalathang	2650m	842mm	Kamzhing	11/8/99
Paro	2300m	1226mm	Kamzhing	10/9/99
Yusipang	2600m	673mm	Kamzhing	20/8/99

Establishment

Seeds were broadcast sown in well prepared seedbeds at the rate shown in Table 3 and 4. In Experiment 2 Mixture 7 was included for Bathpalathang only. The seeds of lotus and lucerne were inoculated by covering seeds with the soil (approximately 2kg per plot) from existing healthy plots of lotus and lucerne. Individual plots were fertilized at the rate of $68.4\text{kg}\text{ha}^{-1}$ of P_2O_5 during establishment. The same fertilization rate was applied in spring each year. The mixture treatments were managed by cutting for all experimental sites. The on-farm sites were managed by the respective households as per their common practice.

Table 3: Mixture composition in Experiment 1

Species	Seed rate (kgha^{-1})						
	Control	Mixture	Mixture	Mixture	Mixture	Mixture	Mixture
	1	1	2	3	4	5	6
White clover	3.75	2	3	2	2	3.75	-
Lotus	-	-	-	-	-	-	5
Cocksfoot	17.5	2	2	2	2	5	17.5
Tall fescue	12.5	15	10	15	10	12.5	12.5
Perennial ryegrass	-	5	5	5	5	-	-
Foxtail meadow	-	10	-	-	2	-	-
Awnless brome	-	-	25	-	15	-	-
Red fescue	-	-	-	7	5	-	-
Common meadow	-	-	-	-	4	-	-
Italian ryegrass	7.5	-	-	-	-	5	7.5

Table 4: Mixture composition in Experiment 2

Species	Seed rate (kg ha ⁻¹)							
	Control	Mixture 1	Mixture 2	Mixture 3	Mixture 4	Mixture 5	Mixture 6	Mixture 7
White clover	5	5	5	5	-	5	-	5
Lotus	-	-	-	-	-	-	8	-
Lucerne	-	-	-	-	20	-	-	-
Cocksfoot	17	-	-	-	-	-	-	-
Tall fescue	17	20	-	-	20	10	20	-
Italian rye	7	7	-	-	7	-	7	
Praire grass	-	-	50	-	-	10	-	-
Dallis grass	-	-	-	30	-	5	-	-
Awnless brome	-	-	-	-	-	-	-	30

Measurements

Species composition: Species composition of mixture treatments for all experimental sites was measured in frequency of appearance of individual species in a frame of 0.25 x 0.25m. Frames were randomly placed 10 times per plot and the plant frequency of species within a frame was recorded. These measurements were carried out at the time of first harvest in late spring (i.e. May). This method may not have provided an accurate estimate of the contribution of species to the biomass production but it certainly provided a good estimate of the trends of individual species present in the plant cover. In the western region, herbage samples weighing over 300gms were collected from 1m². The herbage samples were sorted into individual species and weighed. The weights of individual species were converted into percentages of the total weight of samples from 1m².

Herbage yield: All plots were clipped 3 times annually. Samples for dry matter yields were measured from frames (50 x 50cm) randomly placed four times in each plot to estimate fresh herbage yield from an area of 1 m². The herbage inside each frame was harvested and weighed. The herbage from four frames were bulked and thoroughly mixed. The bulked materials were sub sampled (Grant 1981) and a representative sub sample weighing over 300g was collected from each plot for

subsequent dry matter analysis. Sub samples were oven dried at 60 °C for 24 hours before being weighed for dry matter.

Data Analysis

The raw data were tested for equal variances and normality of distribution. The entire dataset was analyzed using statistical software Minitab Release 14 (McKenzie and Goldman 2005). One way analysis of variance was performed on field variables to compare annual dry matter yields of mixture treatments. The species compositions were not compared between mixture treatments because mixture treatments differed from each other in number and type of pasture species. However, it was possible to compare species composition of individual mixture treatments between years. Fisher's LSD (least significant difference) was used to test the significant differences in dry matter yield and species composition of mixture treatments.

RESULTS AND DISCUSSION

Dry Matter Yield

Yields were generally low for all the treatments.

Experiment 1 (1996-1999): Mixture treatments had no effect on the dry matter yields (Table 5). Lowest yield in the on-station trial was observed for the mixture containing lotus. Beside the screening trials carried out in the 1970s this is the first time that the yield data are available comparing white clover with lotus mixtures under Bhutanese conditions. Yields were generally lower from the on-farm trials in the final year. This may be partly due to grazing and other unaccounted management interventions.

Table 5: Dry matter yield in first Experiment 1

Mixture treatment	Dry matter yield (tha ⁻¹) (Average of 3 cuts)					
	On-station (east central)		On-farm (east-central)		On-farm (west)	
	1997	1999	1997	1999	1997	1999
Control	3.90	4.75	3.73	2.49	3.40	2.51
Mixture 1	3.96	6.10	4.11	2.58	3.35	2.53
Mixture 2	3.69	4.10	2.70	2.49	3.29	2.52
Mixture 3	3.75	4.47	3.33	2.47	4.29	1.54
Mixture 4	3.87	4.95	3.41	2.45	3.27	1.51
Mixture 5	3.83	4.90	4.51	2.62	3.31	2.48
Mixture 6	3.45	3.14	4.35	2.91	3.40	2.52
<i>P</i> value	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>

Experiment 2 (1999-2002): The second experiment generated data comparing yield of lucerne mixture with white clover and lotus mixtures. Except at Khangkhu, the annual dry matter yield did not differ significantly between mixture treatments over the entire study period (Table 6). The lucerne mixture at Khangkhu consistently gave a significantly higher yield than lotus mixture. Yields of mixture treatments were lower in 2002.

Table 6: Dry matter yield in Experiment 2: Figures with same letters in each row are not significantly different

Dry matter yield (tha ⁻¹) (Average of 3 cuts)									
Year	Control 1	Mixture 1	Mixture 2	Mixture 3	Mixture 4	Mixture 5	Mixture 6	Mixture 7	P value
Jakar									
2000	3.47ab	3.45ab	3.70b	2.28ab	1.68a	3.75b	3.20ab	2.32ab	<i>ns</i>
2002	2.48	2.44	2.10	2.04	1.52	2.11	1.72	1.96	<i>ns</i>
Yusipang									
2000	3.10	3.40	3.23	3.34	2.60	2.38	3.72	-	<i>ns</i>
2002	2.82	2.81	2.12	2.28	2.90	2.09	3.03	-	<i>ns</i>
Khangkhu									
2000	2.04abc	2.08abc	1.69ab	2.35bc	2.87cd	2.04abc	1.52a	-	<0.01
2002	0.93ab	0.59a	0.87ab	1.13ab	1.62bc	1.16ab	0.57a	-	<0.05

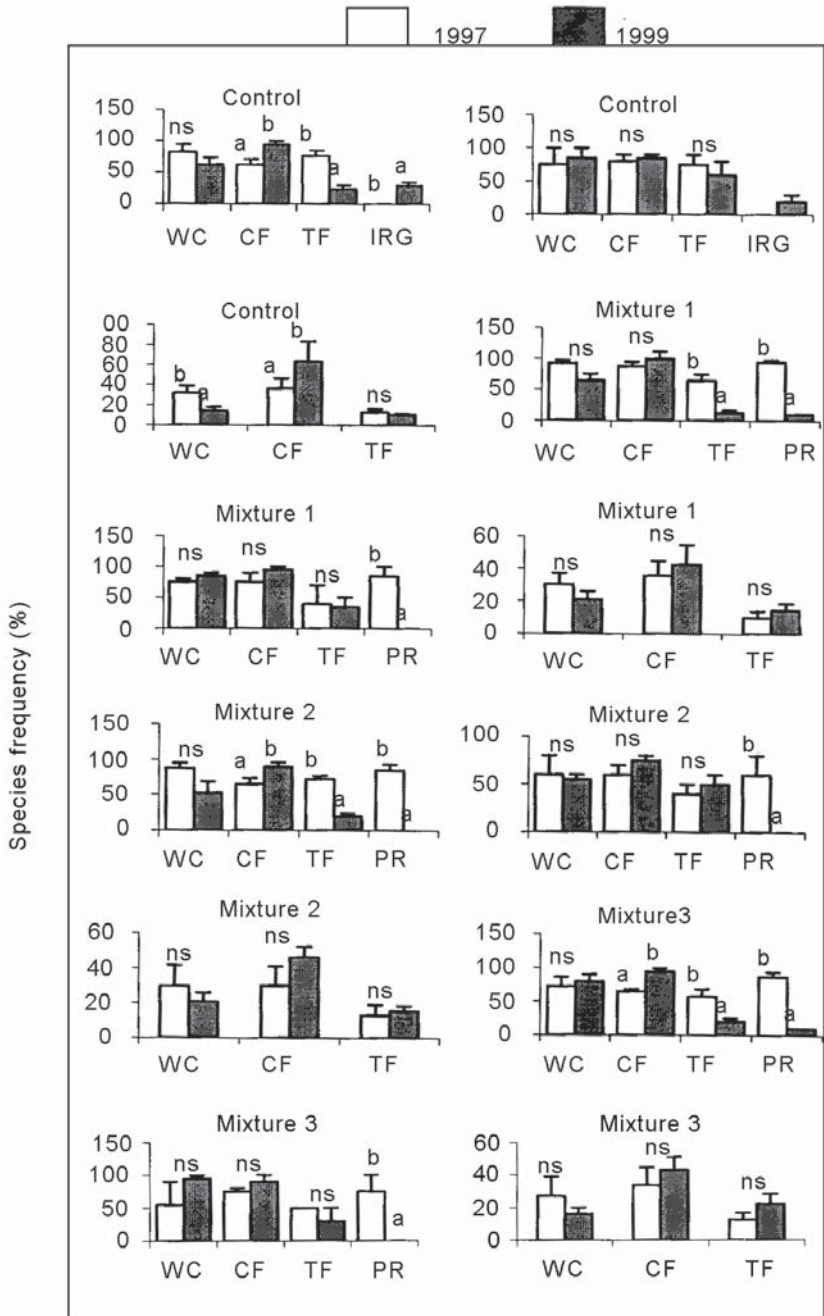
Species Composition

Experiment 1(1996-1999): All grass species except awnless brome established well with good plant densities in 1996. The frequency of all grass species except cocksfoot declined in the succeeding years (Fig. 1). The decline in species composition was especially strong for perennial ryegrass indicating that perennial ryegrass is not suited for the prevailing conditions. A decline in frequency was expected for Italian ryegrass only as this species is considered to be a short lived perennial. The long period with moisture stress strongly favoured cocksfoot. Cocksfoot is well known to tolerate drought (Norris and Thomas, 1982) and thrive on less fertile soils (Kemp et al., 1999). This study did not investigate soil parameters but given the low level of P and dry winter in temperate environments it is apparently difficult for all other grass species including tall fescue and Italian ryegrass to compete with cocksfoot.

Experiment 2 (1999-2002): Tall fescue disappeared in the following years while the frequency of Italian ryegrass declined significantly in the recommended mixture (Fig. 2). However, in the absence of cocksfoot in recommended mixture the frequency of tall fescue increased significantly at Yusipang and Khangkhu. These results further demonstrate that the given conditions favour cocksfoot over other grass species. Unlike Bathpalathang and Yusipang, the frequency of Prairie grass and Dallis grass increased significantly at Khangkhu. Similarly, the frequency of lucerne was comparatively higher at Khangkhu. Khangkhu is warmer and drier than the other experimental sites and thus it was expected that Dallis grass and lucerne would perform well at this location. The mixture with lotus appears inferior to white clover and Lucerne mixtures in most situations. A severe cold and dry winter may have led to the decline of lotus.

Grass component in the mixture had no effect on dry matter yield. For example, in Experiment 2 the increase in the frequency of Dallis grass and Prairie grass did not increase the dry matter yield of their respective mixtures at Khangkhu. Similarly, a decline in frequency of Prairie grass at Bathpalathang and a decline in frequency of Italian ryegrass at Yusipang did not affect dry matter yield.

Manipulation of seed rate or companion grass species had no effect on frequency of white clover, cocksfoot or tall fescue (Fig 1 and 2). Awnless brome (Experiment 1), Prairie grass and Dallis grass (Experiment 2) had the highest seed rates yet their contribution to the total species composition was almost negligible except at Khangkhu. This further confirmed that the variation in seed rates offers limited opportunities to influence species composition.



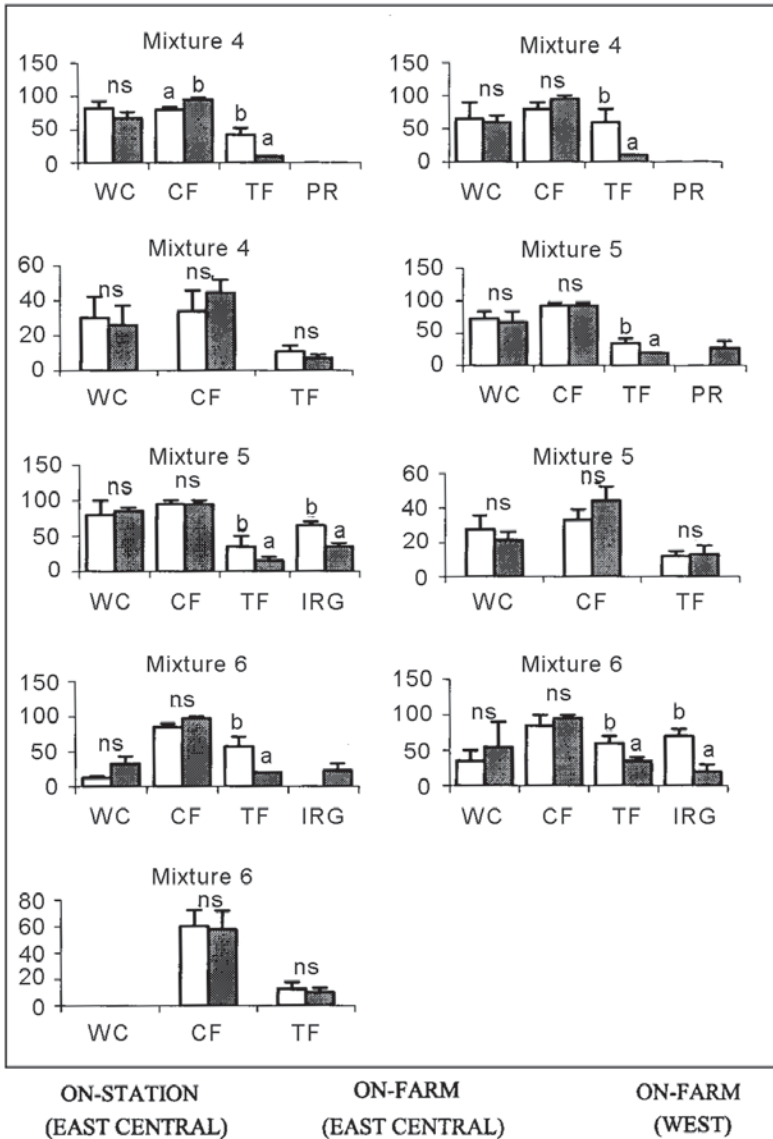
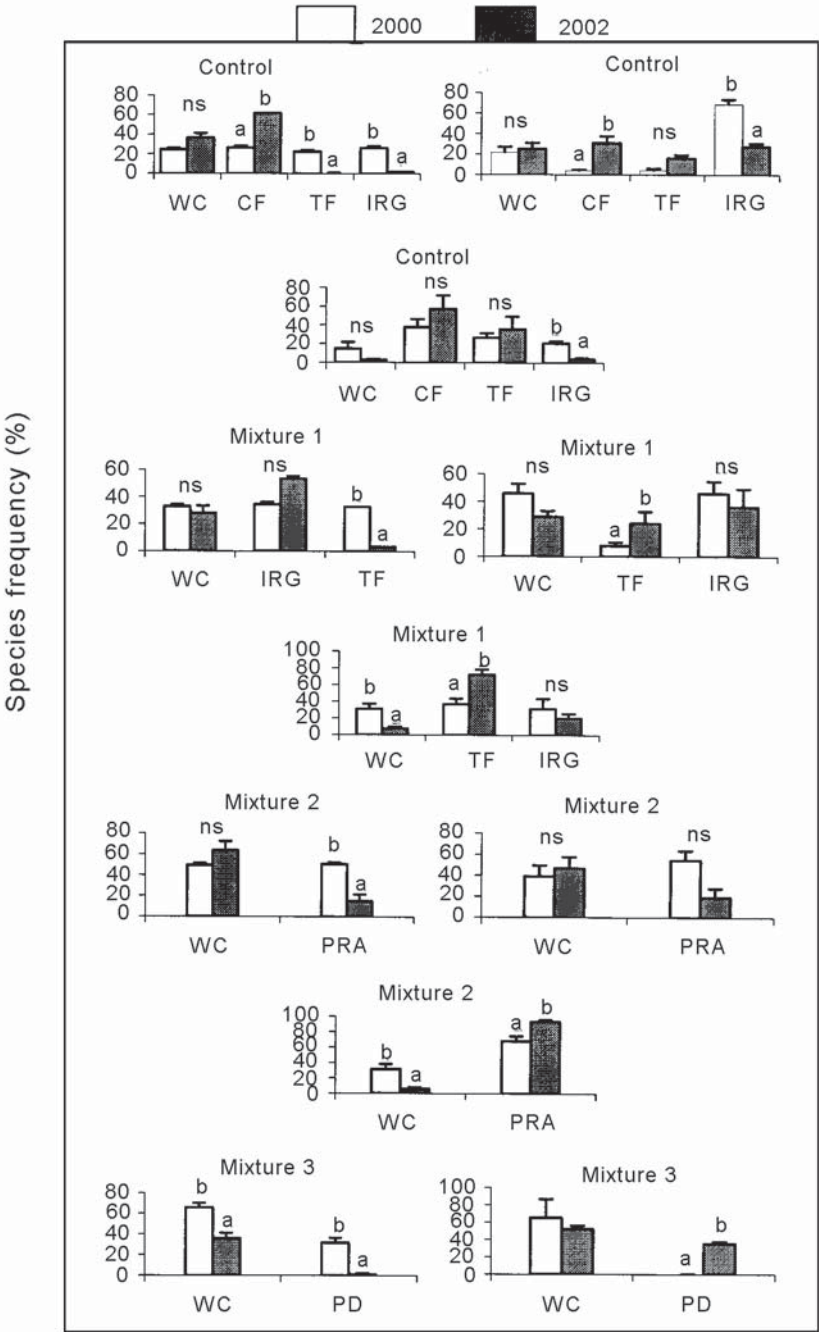


Figure 1: Species frequency of grass and legume species in Experiment 1. Means with different letters within each species category are significantly different. Error bars represent standard error of means and are shown to indicate variability between replicates and on-farm sites. WC-White clover, CF- Cocksfoot, TF- Tall fescue, IRG- Italian ryegrass, PR- Perennial ryegrass. Ns-non significant



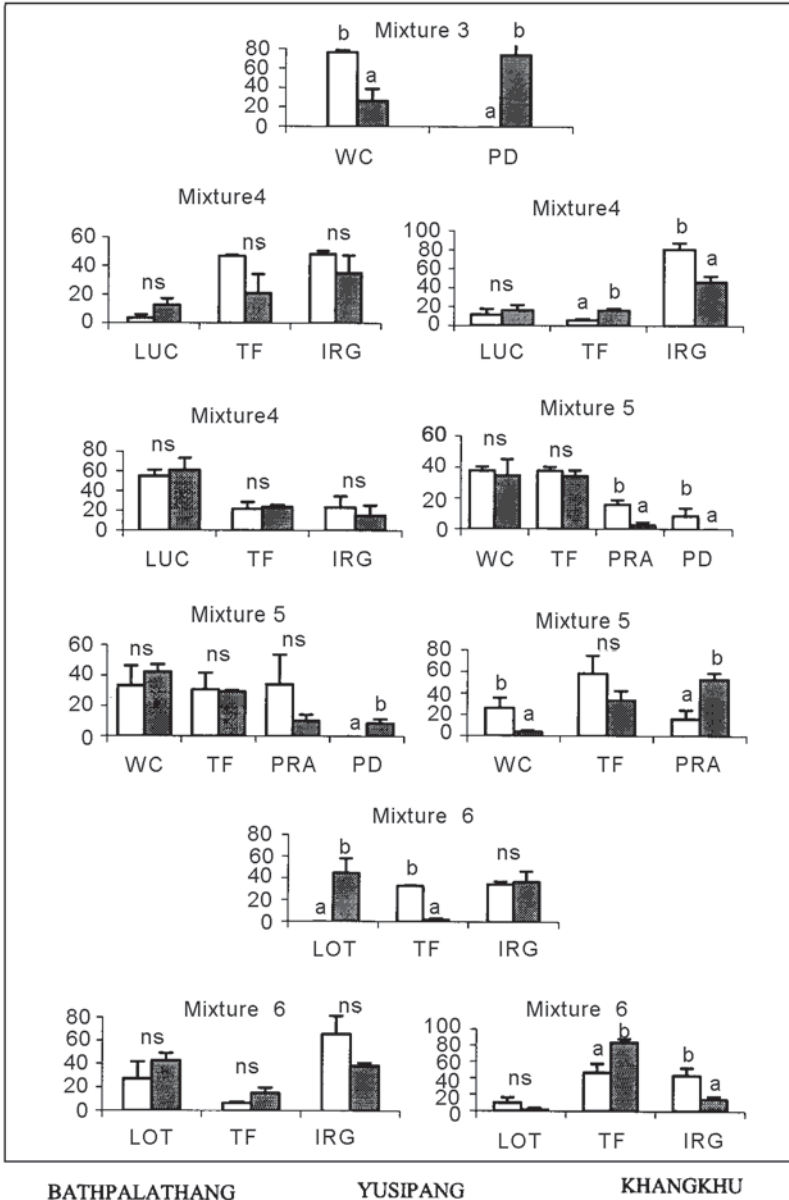


Figure 2: Species frequency of grass and legume species in Experiment 2. Means with different letters within each species category are significantly different. Error bars represent standard error of means and are shown to indicate variability between replicates. WC- White clover; CF- Cocksfoot, TF- Tall fescue, IRG- Italian ryegrass, LOT- Lotus, LUC- Lucerne, PRA- Prairie grass, PD-Dallis grass. Ns-non significant.

CONCLUSION

The findings from these studies and observations made in farmers' fields indicate that species successful in monocultures may not always be successful when grown in mixtures. For identifying species suitable for mixtures it is important to understand the growth pattern of species, species response to defoliation and fertility management and species ability to thrive in stressful environments. Considering huge variations in dry matter yield and species composition of grass-legume mixtures between locations, the current blanket recommendation of a single mixture for all temperate environments should be revised. Specific grass-legume mixtures should be identified for specific locations. Tall fescue should be used in mixtures without cocksfoot.

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Assessment of Calf Mortality in Trongsa and Bumthang

R.B Gurung¹

ABSTRACT

Study on calf mortality was conducted in two districts of Bumthang and Trongsa covering nine blocks and 191 households. Data was collected using semi-structured questionnaire. Results revealed that the average calf mortality rates were 28.5% and 38.5% in Bumthang and Trongsa, respectively with mean of $33.5\% \pm 14.2$. Maximum calf mortality was recorded in Jersey cross (36.4%) and Siri (Thrabum) (35.1%) followed by Brown Swiss cross (21.8%). Over period of one year mortality was similar except for the month of June and July, which experienced higher calf mortality rate of 17.7% and 13.2%, respectively. The study also found that maximum numbers of calf died at the age of one to twelve months. General weakness, Calf scour, Black Quarter and wild animal predation were main causes of calf mortality. Need to improve calf management skills of the farmers and review of the existing vaccination schedule was recommended.

KEYWORDS: Calf mortality, farmers, breeds, management, black quarter.

INTRODUCTION

Cattle in Bhutanese villages are generally managed under extensive grazing system with calves allowed to roam freely with the dams. This makes calves vulnerable to adverse weather condition, stress and predator attack. Proper management of calf is an important aspect of profitable cattle farming. Any loss of calf directly affects the performance of the farm.

Calf mortality management varies with the type of farming enterprise. In some intensive breeding farms, a breeder usually raises all heifers and bull calves, and sells the surplus as breeding stock. The surplus animals of low genetic quality are salvaged from young age thereby avoiding calf mortality. Specialized dairy farmers rear all their female calves but dispose off their surplus male calves at or soon after birth. However, the marginal Bhutanese cattle farmers rear both male and female calves irrespective of the breed for their multiple uses such as milk, draught power

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and manure. This may be a desirable option for marginal farmers but even such farming enterprises are reportedly limited by high incidence of calf mortality. Tamang and Perkins (2005) noted that calf mortality in Bhutanese village farms is seen as causing double loss, i.e. loss of both calf and dam's milk. However, Tamang et al (1993) mentioned that it is unknown to Bhutanese farmers the actual values of died calf and likewise the economic loss.

Calf mortality in the tropics and subtropics are often as high as 50% but this are almost invariably linked with poor management (Williamson and Payne, 1975). The most common cause of calf death is attributed to 'scouring' disease. The young calves could be susceptible to attack by internal parasites and conventional livestock diseases such as Foot and Mouth Disease (FMD), Black Quarter (BQ), Hemorrhagic Septicemia (HS) and Anthrax leading to their mortality. However, comparative studies about the level of calves' mortality in different places in Bhutan and the causes of death are not adequately documented. This study was therefore conducted with the following objectives:

- Establish calf mortality rate at farmers' level in these two districts of Bumthang and Trongsa comparing mortality rate between districts, blocks, breeds of cattle, sex, age, different seasons of the year and
- Formulate strategic plans to reduce mortality rate.

MATERIALS AND METHODS

The study covered two districts in east central Bhutan, namely Bumthang and Trongsa. A total of nine blocks (Korphu, Langthel, Drakten, Tashiling and Nubi from Trongsa) and (Chumey, Tang, Ura and Choekor from Bumthang) were included involving 191 households. A time period of one year (December 2003 to November 2004) was set for this study to find the pattern of mortality during different months and seasons in a year.

A Simple Random Sampling (SRS) was applied to collect the required information (Cameron, 1999). Confidence interval (95%) was selected with variance of 0.05 to conduct interview in 90 villages (10 villages in each block).

The required information was collected using a semi-structured questionnaire. The format was designed to capture information including details of the owner, total cattle population, total calf population during the period, sex of calf, causes of death, age at death, predation by wild animals, vaccination/treatment history and management. Collection of information was based on the recall method since farmers rarely keep farm records. The data were analyzed using Microsoft (MS) Excel 2000.

RESULTS

Calf Mortality in Bumthang and Trongsa Districts and Between Blocks

The calf mortality rates were 28.5% and 38.5% in Bumthang and Trongsa, respectively with mean of $33.5\% \pm 14.2$. The calf mortality incidences did not show any significant difference between the two districts ($P > 0.05$).

In the selected blocks, the highest calf mortality was in Tang, Bumthang (35.48%), and in Drakteng, Trongsa (56.10%), (Table 1). The lowest rate was in Chumey, Bumthang (16.84%), and in Nubi, Trongsa. (25.00%),

Table 1. District and block calf mortality

District	Block	% Mortality	Average
Bumthang	Chumey	16.8	28.5
	Tang	35.4	
	Ura	35.0	
	Choekor	26.9	
Trongsa	Korphu	48.0	38.5
	Drakten	56.1	
	Langthel	26.4	
	Tangsibji	37.2	
	Nubi	25.0	

Mortality Rate between Breeds

Highest mortality was recorded for Jersey cross¹ and Siri (*Bos indicus*) breeds-locally known as *Thrabam*. The mortality rate in these two breeds were (36.4%) and (35.1%) respectively, followed by Brown Swiss (BS) cross (21.8%). The lowest rate of mortality was in Mithun (*Bos frontalis*) cross (6.4%). However, these mortality rate between the breeds were not significantly different except between Mithun cross and *Thrabam*; and between Mithun cross and Jersey cross, with $P < 0.05$ ($P = 0.01$ and $P = 0.03$, respectively).

Mortality Rate Between Sexes

The mortality rate among the male-female was 34.1% and 33.7%, respectively. Mortality rate was not influenced by sex as there had been no significant differences the sex ($P > 0.05$).

¹ Jersey and mithun are generally crossed with Siri

Mortality Rate in Different Months of the Year

The pattern of death over period of one year (Fig.1) was similar except for the month of June and July, which experienced higher incidence of calf mortality.

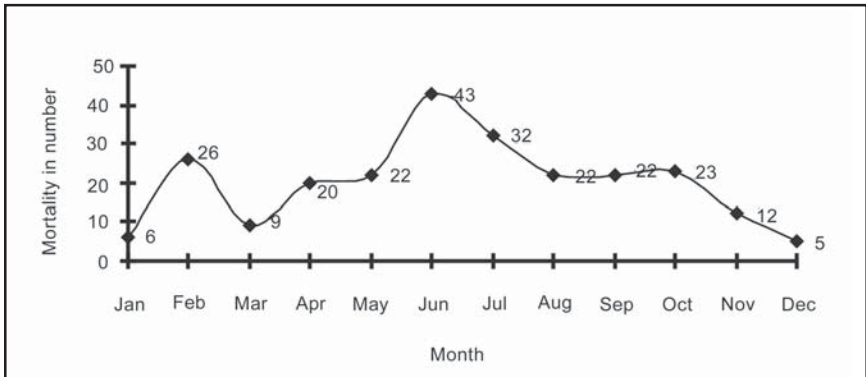


Figure.1. Mortality rate during different months of the year

Table 2: Cause of calf mortality

Causes of calf Mortality	%Mortality
Weakess	17.8
Calf scour	16.9
Black quarter	15.6
Wild animal predation	14.8
Accident	11.0
Coccidiosis	5.5
Bloat	4.6
Unknown cause	13.5

Mortality Rate among Different Causes

Besides weakness, the most common cause of calf mortality was Calf scour, bacterial disease, black quarter and wild animal predation.

Mortality Rate between Age Groups

Maximum number of calf death occurred at the age of one, six and twelve month (Fig.2). However, the mortality rate in different age groups (3, 6, 9 and 12 months) was not significantly different ($P > 0.05$).

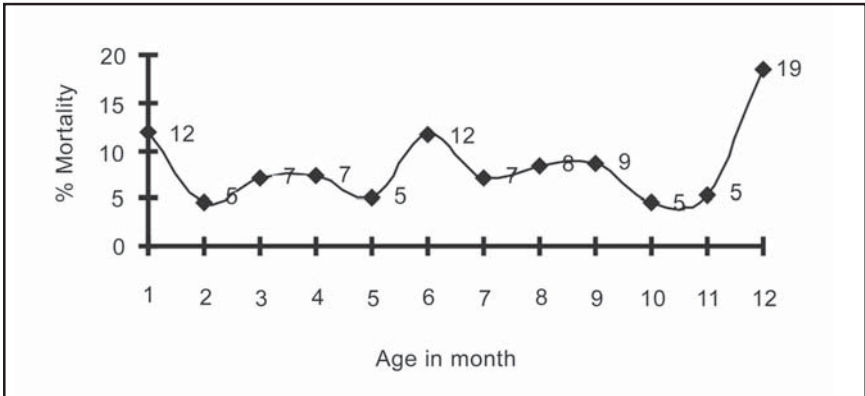


Figure 2: Calf mortality at different age

DISCUSSION

The overall calf mortality rate in the study area of two districts was 33.5%. This indicates that out of every three calves born one would not survive for more than 12 months of age. This mortality rate was moderately higher than 22% reported earlier for Bumthang district by Tamang *et al* (1993) and 24% reported for selected areas of western Bhutan by Tamang and Perkins (2005). This mortality figure in the village condition is also higher than the mortality rates reported for Government farms, 13.9% in National Jersey Breeding Centre (NJBC) (Wangchuk, 2004) and 10% in Brown Swiss Farm (BSF) (Dorji, 2003). Despite differences in the climatic condition between Bumthang and Trongsa districts, there was no significant difference in the calf mortality pattern. This indicated that irrespective of breed types, variation in climate did not affect mortality pattern. However, within the same environment, some breed types were more susceptible to disease condition than others. For instance, Jersey cross calves were more prone to diseases thereby leading to higher deaths. Less adaptability of this breed type than other could have resulted this. Unobservable difference in mortality between sexes was due to provision of similar type of management at the farmer's level for both the sex. Thus, unlike in many countries, where female calves get preferences over males (Williamson and Payne, 1975; Fraser *et al.* 1991), it was not the case in these two districts. Ambient microbes and infecting host are normally most active during warmer seasons of the year. This could be the reason for higher number of calf

deaths in the month of June and July. In general, calf scour are reported to be the main factor that causes mortality (Williamson and Payne, 1975; Fraser *et al.* 1991). Given appropriate management practices, calf scour could actually be controlled. The high incidences of calf scours in the study area suggest that our farmers still need to improve management skills.

The high calf mortality at the age of one month could be because cattle owners fail to provide the required level of management and care to the young ones. Vulnerability to BQ and predation by wild animal could explain maximum calf deaths occurring at 12 months of age. This age coincides with majority animals attaining better health and weight gain. The healthy calves are usually more susceptible BQ than the weaker ones. Further it could be possible that high incidence of BQ in the study area could also be related to vaccination failures.

CONCLUSION

Investigation of calf mortality pattern in Bumthang and Trongsa revealed that Jersey cross and *Thrabum* calves were more prone to death followed by BS calves. Most calves in the study area died at the age of 1, 6 and 12 months. Calf scour and BQ were important cause of deaths. Since calf scour are linked to management deficiencies, there is need to create awareness on improved husbandry practices. Further, annual vaccination and deworming schedule being advocated may have to be reviewed. A follow up investigation would be required to ascertain the real cause of calf mortality. This would enable effective monitoring of management system being advocated and change in the vaccination schedules if warranted.

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Incidence and Distribution of the Apple Fruit Borer *Argyresthia Conjugella* Zeller (Yponomeutidae: Lepidoptera) and Its Chemical Control in Western Bhutan.

Chencho Dorji¹ & Phuntsho Loday¹

ABSTRACT

*The apple fruit borer *Argyresthia conjugella* Zeller (Yponomeutidae:Lepidoptera) is found to be a serious pest of apple (*Malus domestica* Borkh.) in the high altitude apple growing areas in Bhutan. More than 80% of fruits can be infested in a particular season. Adult moths were caught by first week of May and infestation on fruits was first detected by mid week of July when the average size of fruits was between 30 to 45 mm in diameter. Two timed cover sprays with Chlorpyrifos 20% EC, at two week interval has been found to give effective control of the fruit borer. Three wild host plants (*Malus baccata*, *Malus sikkimensis*, and *Pyrus pashia*) all belonging to the Rosaceae family are confirmed to be the hosts of the fruit borer.*

KEYWORDS: Apple fruit borer, pests, wild host plants, chemical efficacy

INTRODUCTION

The apple fruit borer, *Argyresthia conjugella* Zeller (Yponomeutidae:Lepidoptera) is a serious pest of apple in Bhutan. It is widespread in the districts of Haa and Bumthang and also occurs in the high altitude apple growing areas in the district of Thimphu and Paro. In Bhutan, its presence was first detected when the moth was reared from apple fruits collected from Serbithang, Thimphu in 1987. In August 1995, the first major problem of the fruit borer was observed in Haa. Since then, the fruit borer has been observed in most of the high altitude apple growing areas in Bhutan. The apple fruit borer is reported to be a serious pest of apple fruits in Himachal Pradesh, in North India (Khajuria *et al.*, 1986). It is also reported as a major pest of apple in Europe, Asia and North America (Belosel's Kaya, 1963).

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The adult is a tiny moth with a triangular white patch of hair on the dorsal side of the thorax. The moth probably lays its eggs in the month of June and the first instar larva on hatching, enter the fruit and burrow till the seed pocket. The entry point of the larvae is a tiny pinprick mark covered with white crystalline ooze, often with a slight depression on the skin of the fruit. Attacks by this pest are often overlooked until close to harvest when it is too late to control the pest. Larvae feed on the developing seeds reducing them into a brown colored mass. The larval period is reported to vary with temperatures from 30 to 90 days (Edland, 1965). Infested fruits drop prematurely and will soon rot causing losses in yield. The presence of the larva in fruits can also affect the quality of the fruit particularly for export. Mature larvae come out of the fruit and pupate under the debris and the bark of trees and the moth is reported to have one generation a year (Khajuria *et al.*, 1992).

Apple is one of the most important cash crops in Bhutan, next only to Potato and Mandarin. During the last two decades, the cultivation of apple has grown tremendously because of its export opportunities to neighboring countries like India and Bangladesh. Apple is now extensively grown in the western districts of Thimphu, Paro and Haa and in the central district of Bumthang. In 2003-2004, a total quantity of 3816 metric tons of apple has been exported to India and Bangladesh earning a cash return of about Nu.31 million (Marketing Division, MOA).

In Bhutan, grower recommendations for the control of apple pests included four to five regular or calendar chemical sprays from spring through to the autumn harvest. This resulted in excessive use of pesticides often leading to resurgence of secondary pests like the Fruit tree red spider mite, *Panonychus ulmi* (Koch) and the San Jose scale *Quadraspidiotus perniciosus* (Comstock). Very little information existed on the apple fruit borer in Bhutan with regard to its economic importance, distribution, alternate hosts and other ecological information to come up with an appropriate field control program. This study therefore concentrated on finding out:

- (i) Incidence of the apple fruit moth and its distribution.
- (ii) Wild/alternative host plants of the apple fruit moth
- (iii) An effective and minimal chemical sprays required to control the apple fruit moth, through proper timing of chemicals.

It has been reported that there is no attack by the apple fruit moth on apple when the natural and highly preferred host, the mountain ash, *Sorbus aucuparia* L produces enough berries to support the moth population in a particular area (Edland, 1969). This enabled us to undertake the study on a survey of wild hosts in Bhutan together with the infestation level of the fruit moth both in apple in wild hosts. This would help us to establish not only the infestation level of the apple fruit moth in apple and the wild hosts but would also indicate whether apple is a preferred host to its wild alternatives. This is essential as the main factor in

determining the severity of attack on apple has been established to be correlated with the relationship between the population densities of the moth in the area with the amount of the berries borne by the primary host, the mountain ash (Edland, 1969). In an evaluation of chemicals and spray schedules, it was found that two timed sprays with fenthion gave not only effective control of the fruit moth but was also found to be the most economical (Sharma *et al.*, 1988). Since fenthion was not available in Bhutan, we investigated the efficacy as well as the timing of different available chemicals to come up with an efficient field control program for the apple fruit moth. This would help us to replace the calendar or routine spray programs with a well timed minimal spray schedule saving costs on control operations as well as undesirable environmental effects.

MATERIALS AND METHODS

Field Sites

The chemical efficacy and host plant related studies were carried in orchards spread over four geogs (blocks) of Sammar, Isu, Katsho and Bji in Haa district at an altitude of about 2800 m above sea level. Research to detect the fruit moth, both through dissection of apple fruits and pheromone trappings were also carried out in several places like Yusipang, Hongtsho, Serbithang and Genephu in Thimphu district and Shari, Dotey and Drugyel area in Paro district. The altitude of these places ranged between 2400 to 2600 m above mean sea level. The research period spread over five years from 1996 to 2000.

Incidence of the Fruit Moth

Dropped fruits from three different locations were sampled every two weeks starting from 3rd July to 25th September both in 1996 and 1997 to find out the period and the incidence of the fruit borer. From the dropped fruits collected, twenty fruits were randomly selected and then dissected for the fruit borer infestation.

To establish the infestation level of the fruit borer in a control orchard in Haa, fruits from trees as well as dropped fruits were monitored in 1997. Twenty fruits were randomly selected both from the dropped fruits and fruits still remaining on the trees and dissected to detect the incidence of the fruit moth. Fruit dissection was carried out on 28th August 1997 and on 11th and 25th September.

In 2000, an apple orchard at Genephu, Thimphu was weekly monitored for fruit development by measuring the diameter of 10 randomly selected fruits. Simultaneously, the presence of the adult moth was observed both visually as well as by placing sex pheromone traps and fruits were also monitored for signs of infestation.

Efficacy of Chemicals

Preliminary investigative studies in Ha in 1996 indicated that seven cover sprays with either Cypermethrin 10% EC or Chlorpyrifos 20% EC were very effective in controlling the fruit borer. Chemical efficacy trials in 1997 therefore concentrated in establishing the minimum number of sprays required as well the timing of chemical applications to obtain an effective control of the fruit borer. Seven orchards were selected in from four geogs (blocks) in Haa and of these five orchards were sprayed with Chloropyrifos at different times and with different number of applications. One orchard was sprayed with a Neem derivative, Nimdin-K and another one was kept as control (Table. 1). To check for infestation of fruits, twenty dropped fruits and thirty fruits from trees were randomly collected and dissected every two weeks on 28th August, 11th and 25th September 1997.

Table 1: Schedule of Chemical sprays for different treatments in 1997

Treat ment	Dosage/ 1 litre of water	No. of times sprayed	Spraying dates						
Chlor 2	4 ml	2	-	-	-	17/7	31/7	-	-
Chlor 3	4 ml	3	-	-	-	17/7	31/7	14/8	-
Chlor 4	4 ml	4	-	-	3/7	17/7	31/7	14/8	-
Chlor 5	4 ml	5	-	19/6	3/7	17/7	31/7	14/8	-
Chlor 7	4 ml	7	5/6	19/6	3/7	17/7	31/7	14/8	28/8
Nimdin-K	5 ml	7	5/6	19/6	3/7	17/7	31/7	14/8	28/8
Control	-	0	-	-	-	-	-	-	-

Chemical efficacy trials in 1997 indicated that two cover sprays might be adequate to effectively control the apple fruit borer. This result is in line with the conclusions of studies carried out in Himachal Pradesh in India (Sharma *et al.*, 1988). Therefore chemical efficacy trial in 1999 was targeted to establish the best or the most effective time of chemical cover sprays. Three orchards were treated with Chloropyrifos at different periods of time and one orchard was kept as control (Table 2). Twenty fruits were randomly selected from dropped fruits and dissected to observe for the fruit borer. Dropped fruits were dissected every two weeks on 22nd July, 4th August, 20th August and 2nd September. Fruits on trees were monitored twice on 20th August and 2nd September through random collection of twenty fruits and subsequent dissection.

Table 2: Chemical spray (Chloropyrifos 20% EC) schedule for different treatments in 1999

Treat ment	Dosage/ 1 litre of water	No. of times sprayed	Spraying dates					
T1	4 ml	2	1/6/99	11/6/99	-	-	-	-
T2	4 ml	2	-	-	21/6/99	1/7/99	-	-
T3	4 ml	2	-	-	-	-	12/7/99	22/7/99
C	-	0	-	-	-	-	-	-

Survey of Wild Host Plants

The mountain ash, *Sorbus aucuparia* L. is reported to be the primary and the highly preferred host of the apple fruit moth in Europe (Edland, 1969). Though eighteen species of *Sorbus* L. has been reported from Bhutan (Grierson & Long, 1987) yet there is no report of the mountain ash as being present. A survey was therefore carried out in Haa in 1999 to detect wild alternative hosts of the fruit moth. Berries from three wild plants under Rosaceae family were collected and fifty fruits randomly selected and dissected on 2nd September 1999 to detect for infestation. Fifty apple fruits were also randomly selected on the same date from an orchard where no chemical has been used and dissected to check for infestation. For rearing the moth, the wild fruits were collected and were kept in a constant temperature insect rearing room in our laboratory at Semtokha, Thimphu. The characters of the larval as well as the adults that emerged from the wild fruits were compared to the apple fruit moth for identification. The wild host plants were identified by a Botanist with the Department of Forest.

RESULTS

Incidence of the Fruit Borer

Larva of the fruit borer was first detected in dropped apple fruits towards end of July both in 1996 and 1997. By September, more than 70% of dropped fruits were observed with the fruit borer indicating the fruit borer to be the major cause of fruit drop towards the later part of the season. Figure 1 shows the infestation level of dropped fruits by the fruit borer. Dissection of fruits on trees from a control orchard in 1997 revealed that by September more than 60% of the fruits were infested by the borer (Figure 2).

Figure 1. Average incidence of fruit borer in dropped fruits from three different locations in Haa

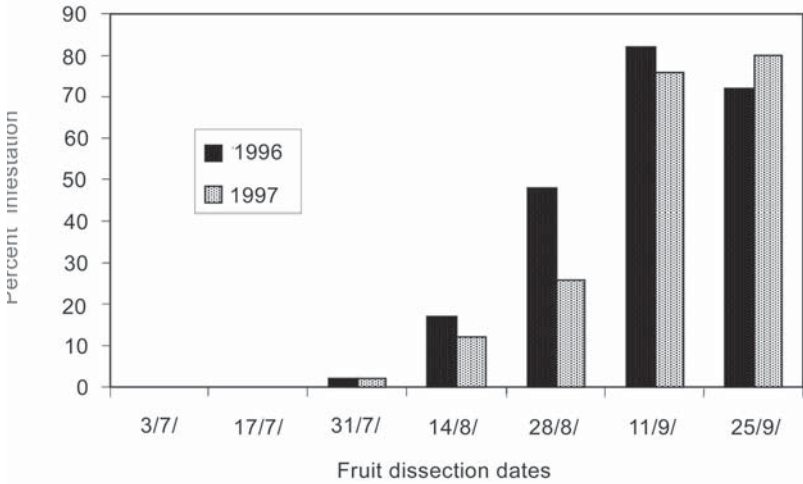
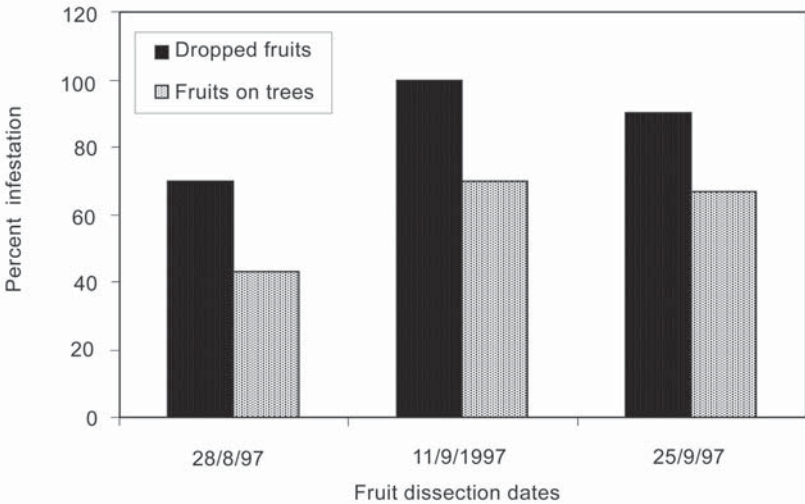
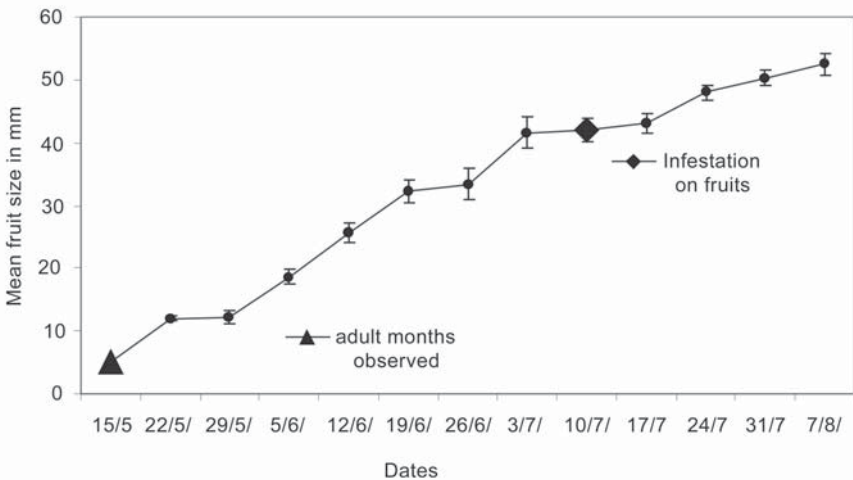


Figure 2. Incidence of the apple fruit borer in a control orchard in Haa



Adult moths were first caught in the sex pheromones traps by 15th May at Genephu, Thimphu and were continued to be caught till 5th June 2000. Infestation by the fruit borer was first detected on 10th July 2000 when tiny holes covered with white crystalline ooze were observed on fruits. The first infestations were noticed when the mean fruit size was about 42 mm in diameter.

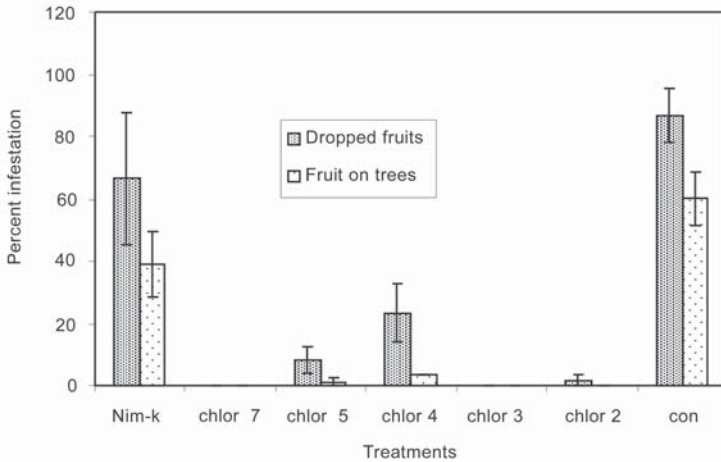
Figure 3. Fruit development at Genephu, Thimphu in 12000



Efficacy and Timing of Chemicals

Effective control of the fruit borer was achieved with the chemical Chloropyrifos. An herbal product of Neem was included in the trial in 1997, but the results obtained were not promising. The results indicate (Figure 4) that two sprays of Chloropyrifos applied in mid and end of July are effective in controlling the fruit borer and that there is no significant difference in the infestation of fruits between orchards with two and seven sprays. Chemical efficacy trials in 1999 concentrating on establishing an optimal time for chemical sprays demonstrated further that two cover sprays with Chloropyrifos were effective in controlling the fruit borer. However, no significant differences were observed in the fruit infestation between the orchards with different chemical application timings (Figure 5).

Figure 4. Fruit infestation by the fruit borer in orchards with different treatments in 1997



Wild Hosts Plants

Three species of wild plants under the family *Rosaceae* were confirmed to be the wild hosts of the fruit borer. These wild hosts are *Malus baccata*, *Malus sikkimensis*, and *Pyrus pashia* and occurred between altitudes of 2600 to 3000m above mean sea level. Figure 6 shows the infestation level of apple fruits to be much higher than in the wild hosts.

Figure 5. Infestation level of fruits by the fruit borer in different treatment orchards in 1999

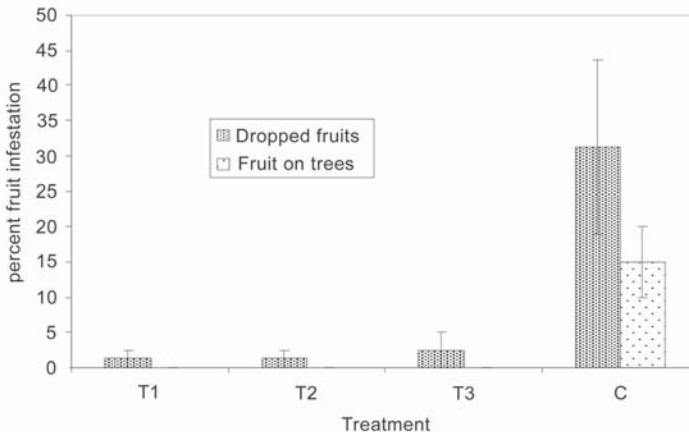
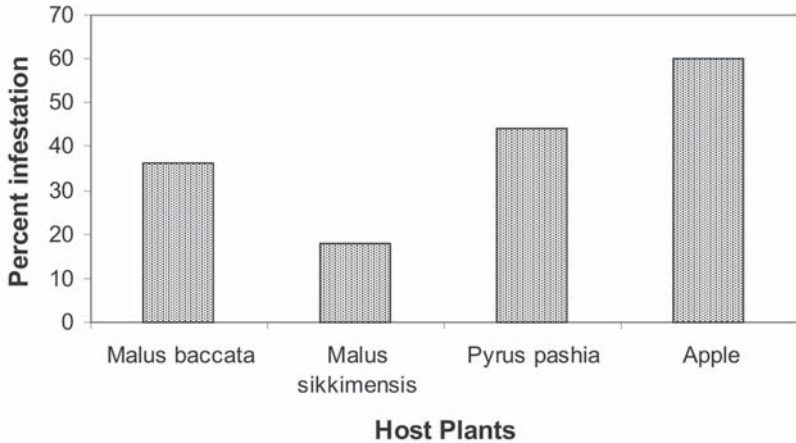


Figure 6. Infestation level of fruit borer in different hosts in Ha in 1999



DISCUSSION

Fruit infestation by the fruit borer indicate it to be a major pest of apple in high altitude apple growing areas with more than 60% and 80% of fruits being infested in fruits on trees and dropped fruits respectively. This is in line with the studies carried out in Himachal Pradesh, India, where the fruit borer is found to have localized between altitudes of 2445 to 2900 m above mean sea level (Khajuria, *et. al.*, 1986). During the study, it was also evident that infestation of fruits by the fruit borer varied in orchards even at the same altitude level. This variation may be due to the specific location of the orchards in relation to proximity to wild host plants, micro-climatic conditions and the variety of the available apple trees in the particular orchard. The varietal preference of the apple fruit borer has been well documented (Khajuria, *et. al.*, 1987).

Trapping and fruit monitoring indicated that the fruit borer emerged by first week of May and first infestation of fruits were observed by second week of July in Genephu, Thimphu, when the fruit size varied between 30 to 45 mm in diameter. The first infestation on fruits was observed after about a month from the emergence of first adult moths. In Haa, larval presence in fruits was first detected by end of July. Khajuria *et. al.*, 1989, found out that infestation of apple fruits started 17 days after adult emergence when the fruit sizes varied between 27 mm to 32 mm in diameter. Further more, they have also shown that the moth activity as well as the initiation of infestation to be highly dependent on the prevailing temperature and weather conditions. Due to variation in temperatures over the years as well between different

locations, it would not be effective or practical to recommend a fixed date for chemical applications for all locations. Apple fruits should be monitored regularly when they have attained an average size of 20 mm in diameter and chemical spray should be carried out immediately after the entry hole of the first instar larva is observed on fruits. Two cover sprays were found to be effective and economical (Sharma, et. al., 1988), which is consistent with the results that we obtained in 1997 and 1999. It is important that the two cover sprays be timed considering the average fruit size in a particular location, about 30 mm in diameter and most accurately, immediately after detection of the entry holes on the fruit. Considering the life cycle of the fruit borer (Edland, 1965) and correlating it with our results, the first cover spray should probably be timed in mid July which can either be brought forward or pushed behind by a period of two weeks depending on the particular environmental condition of the location.

Despite high infestation level detected in wild host plants, the infestation level in apple is higher indicating that apple may be a preferred host of the fruit borer in Bhutan. More study is needed in this area to correlate the infestation level of wild host plants, their distribution pattern and density with the infestation of apple fruits over a few seasons.

CONCLUSION

The fruit borer is a serious pest of apple in high altitude apple growing areas of Bhutan, within the altitude range of 2400 to 2900 m above sea level. Towards the end of the season in September, more than 80% of fruits can be infested by the fruit borer. The variation in infestation level of orchards even at the same level may be due to differences in climatic condition, proximity and distribution of wild host plants and the variety of apple trees grown. Three wild plants all belonging to the *Rosaceae* family are confirmed host plants for the fruit borer. Two timed cover sprays at two week interval has been found to give effective control of the fruit borer. Based on these research findings, the following recommendations are made for the control of the fruit borer:

- Farmers should collect all the dropped fruits in the orchard on a weekly basis and destroy them by burying deep in the soil or by feeding them to cattle. This will help to minimize the fruit borer population over the years.
- Wild host plants in the proximity of the orchards should be destroyed so that natural population of the fruit borer is not supported.

- Two timed cover sprays with Chloropyrifos 20% EC should be carried out when the fruits have attained an average size of 30 mm in diameter (this period would probably be around mid July with two weeks pre- and post adjustments depending on the location). The most accurate time of application would be immediately after detection of the first entry hole on the apple fruits and for this regular monitoring of the fruits is required once the fruits have attained an average size of about 20 mm in diameter.
- Local official bodies like the Dzongkhag Yargye Tshochung (DYT) or the District Development Committee and the Geog Yargye Tshochung (GYT) or the Block Development Committee should be mobilized to create awareness on the problem and community involvement in the control program.

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Minor Cereals and Food Security in the Marginal Areas of Bhutan

Wangda Dukpa¹

ABSTRACT

A random household survey was conducted in 2002-2003 in seven districts with a sample size of 10%, covering 250 households, to document the farming practices of minor cereals (buckwheat, barley and finger millet), their roles in household food security and to assess future potential. The study revealed that barley and buckwheat are predominantly grown in high AEZ and finger millet in mid AEZ respectively. Minor cereals are cultivated under subsistence farming for home consumption. Farmers have mixed perceptions on the cultivation trend and the cultivation practices vary between AEZs. An estimated net return of Nu.2258, Nu.1982 and Nu.156 are obtained per hectare from barley, buckwheat and finger millet respectively. Results revealed that 61% of buckwheat, 37% of barley and 47% of finger millet are consumed as food. Minor cereals supplement rice and maize, and substitute other cereals during the lean period (March-June). The importance of minor cereals in food security at different AEZ and their future potential in the farming systems in the marginal areas are discussed.

KEYWORDS: Minor cereals, food security, marginal areas, Agroecological zones (AEZ), cropping pattern

INTRODUCTION

Agriculture in Bhutan is predominantly subsistence and integrated with crops, livestock and forests. A total of 4, 68,712 ha is agricultural land of which 1, 05,939 ha are under actual cultivation (MoA, 2005). Cultivation of crops ranges from 100 to about 4000 m asl (BSSP, 2000).

Minor cereals include sweet buckwheat (*Fagopyrum esculentum*), bitter buckwheat (*Fagopyrum tataricum*), barley (*Hordeum vulgare*), finger millet (*Eleusine coracana*), foxtail millet (*Setaria italica*), dry land wheat (*Triticum aestivum*), grain

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amaranth (*Amaranthus* spp.), upland rice (*Oryza sativa*) and perilla (*Perilla frutescens*) in view of the relatively low area under cultivation and their contribution to the national food basket. This study covers buckwheat, barley and finger millet while others are not included due to insufficient data.

Sweet buckwheat has dimorphic flowers, pin (long pistils and short stamens) and thrum (short styles and long stamens) and they are self-incompatible (Wang et al., 2005). Bitter buckwheat is self-fertile and produces flowers of only one kind (Joshi & Rana, 1995). Both species of buckwheat were introduced into Bhutan from southern China through northern Myanmar and the Naga Hills and diffused further west to Nepal and Indian Himalayas (Ohnishi & Murai, 1996).

The cultivated barley is classified into four ecotypes, hulled versus naked kernels and two-row versus six-row ears (Fischbeck, 2002). It is further classified into winter and spring types. Isozyme studies revealed that Bhutanese barley varieties were similar to those from Tibet and Ladakh (Konishi, 1992). Therefore, based on the results and historical evidence, the author reported that barley was introduced into Bhutan from Tibet.

Hulse et al. (1980) recognise two ecotypes of finger millet; African highland type (long spikelets, long glumes, short stamens, and with grains enclosed within the florets), and Afro-Asiatic type (short spikelets, short glumes, short lemmas, and with mature grains exposed out of the florets).

About 16.9% of the total cereal area is under buckwheat, barley and millets and these crops contribute 7.9% of the total cereal production (MoA, 2002a). Although their contribution to the national food basket is small, minor cereals are important for household consumption, diversifying the Bhutanese diet and in enhancing household food security and self-sufficiency particularly in the marginal areas. However, no studies in detail has been conducted to determine the importance of these crops and therefore, there is a lack of understanding on the farming practices of these minor cereals. Due to the lack of understanding, not much intervention has been made by the research.

The study was conducted in 2002-2003 with the objectives; a) to assess the affect of climate on crop distribution, growing season and cropping pattern, b) to document the farming practices of minor crops, identify their production constraints and assess economic return, c) to examine the role of minor cereals in household food security and food self-sufficiency and their future potential, d) to provide research recommendations on the improvement of buckwheat, barley and finger millet.

MATERIALS AND METHODS

The study was carried out in collaboration with RNRRCs and Dzongkhag Agriculture Sector. As mandated, the Field Crops Sector of RNRRC-Jakar coordinated the study. Each RNRRC selected Dzongkhag(s) with diverse AEZ where minor cereals are largely cultivated. The study was conducted through household survey, which is a common method and generally it is believed to be formal, explicit, systematic, representative and gives reliable information (Oppenheim, 1992).

With the help of Gups, Tshogpas and Extension Agents sample households were selected from the Gap's register using a simple random sampling method. Sampling covered 10% of the households of the selected geog, which included high, mid and low agro-ecological zones (AEZ). Sampling size was kept low with due consideration of staff shortage and time constraints. However, the study covered different AEZs in order to capture diverse production practices. After sample selection, we prepared the schedule for the survey of the selected households. Tshogpas played vital role in pre-informing the farmers and ensuring survey went smoothly.

Enumerators visited the selected households and conducted face-to-face interviews, as other methods of completing questionnaire described by McNeill (1990) were not feasible. The interview was conducted with the elder member of the household who was knowledgeable about farming in order to obtain reliable information. A total of seven districts and 250 households were interviewed (Table 1).

Table 1: Number of households growing minor cereals in seven Dzongkhags.

Dzongkhag	Sweet buckwheat	Bitter buckwheat	Finger millet	Barley	Total household
Trongsa	5	7	8	1	12
Zhemgang	10	10	9	7	20
Bumthang	49	56	0	58	63
Sarpang	27	8	42	0	58
Samtse	6	1	22	0	29
Tashiyangtse	0	2	13	1	16
Tsirang	8	0	39	5	52
Total	105	84	133	72	250

The completed forms were collated by RNRRC-Jakar. The data of each farmer was coded into numerical forms for easy analyses and the coded data were entered in the ‘Microsoft Excel Spreadsheet’. The data was then analyzed in Microsoft Excel using ‘PivotTable and PivotChart Report’. Data collected in local units were converted to the SI system, tons and hectares. Based on the altitude, households were divided into high (>1800 m asl), mid (600-1800 m asl) and low (<600 m asl) AEZ and analyses were made accordingly.

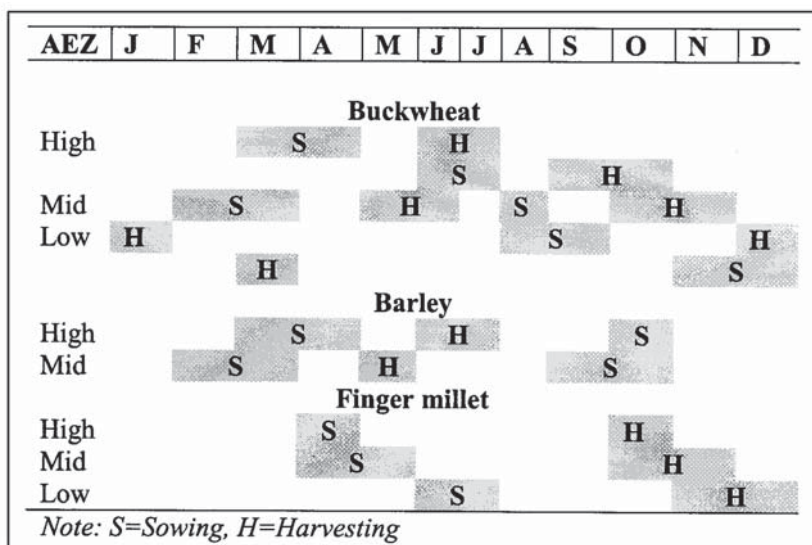
RESULTS

Cropping Pattern

The crop production and cropping pattern is largely determined by the temperature, rainfall and ecotypes. These factors vary in different AEZs. Due to the varying temperature and rainfall, there are differences in the sowing and harvesting dates of buckwheat, barley and finger millet in different AEZs (Table 2).

In high AEZ, buckwheat is grown as spring crop in March-April and harvested in June-July, followed by a summer crop/potato-base planted in June-July and harvested in September-October. In mid AEZ, buckwheat is grown as first crop in March-April and harvested in June followed by a summer crop of rice. It is also

Table 2: Sowing and harvesting dates (months) of minor cereals in high, mid and low AEZ.



grown in August after Maize. In low AEZ, buckwheat is grown as winter crop in November-December and harvested in March, followed by rice in July, in August-September after Maize and harvested in December-January.

Spring Barley is grown in March-April and harvested in June-July while winter barley is grown in October and also harvested in June-July in high AEZ. In mid AEZ, spring barley is grown in February-March and harvested in May-June while winter barley is grown in September-October and harvested in April-May.

Finger millet, in high AEZ, is grown either as intercrop with maize or pure stand in April and harvested in October. It is also grown in June-July and harvested in October–November. In mid AEZ, finger millet is usually grown in April-May and harvested in October-November. In low AEZ, finger millet nursery is established in June and transplanted in July-August, which is harvested in November-December.

Farmers establish buckwheat and barley by direct seeding, broadcasting seeds @ 87 Kg/ha and 73 Kg/ha respectively. Majority of the farmers transplant finger millet (82%) while 18% direct seed by broadcasting seeds @ 20 Kg/ha. Forty two percent cultivate sweet buckwheat, 34% bitter buckwheat, 53% finger millet and 29% barley respectively. Overwhelming percentage of farmers (95%) cultivates winter barley and only 5% cultivate spring barley. No substantial difference was observed between the high and mid AEZ in the cultivation pattern of spring and winter barley. Although there are two blast resistant improved varieties of finger millet available, only 2% cultivate these varieties. There is no improved buckwheat and barley varieties available, thus, farmers cultivate only traditional varieties.

Manure/Fertilizer

Buckwheat, barley and finger millet are grown in the marginal areas with low inputs primarily for home consumption and sustenance. Animal manures are applied as Farm Yard Manure (FYM) and tethering of animals in the field. Animal manures are most commonly applied as FYM in high AEZ, FYM and tethering in mid AEZ and tethering in low AEZ. On an average 61%, 60% and 79% apply manure on buckwheat, barley and finger millet while 25%, 27% and 7% apply fertilizers on buckwheat, barley and finger millet respectively. In general, about 67% of the households apply manure and 20% apply fertilizers. This evidence reveals that soil fertility is primarily maintained through application of animal manure and fertilizers are applied to supplement animal manure. On an average, 3.6, 0.9 and 1.3 t/ha of FYM are applied on barley, buckwheat and finger millet respectively. Fertilizers such as Urea, SSP and Suphala are applied @ 35, 16, 10 Kg/ha and 41, 42, 17 Kg/ha on barley and buckwheat respectively. In high AEZ, 75%, 54% and 18% apply fertilizers on buckwheat, barley and finger millet respectively while none of the farmers in mid and low AEZ apply fertilizers on these crops.

Harvesting and Threshing

Buckwheat, barley and finger millet are dry land crops and therefore, commonly grown in Kamzhing (dry land) across different AEZs. In high AEZ, buckwheat is not grown in wetland (Chuzhing) while in mid and low AEZ, buckwheat is also grown in the wetland as first or second crop and not during the normal rainy season. None of the respondents cultivate buckwheat in shifting cultivation (Tseri). Cultivation of buckwheat in grassland shifting cultivation (Pangzhing) is limited to high AEZ, particularly in Bumthang Dzongkhag. Finger millet is cultivated in wetland, dry land and shifting cultivation but not in grassland shifting cultivation. However, in high AEZ no finger millet is cultivated in wetland. The average area per household under buckwheat, barley and finger millet are 0.61 ha, 0.24 ha and 0.68 ha respectively.

Over 97% of the households harvest barley and finger millet only the spikes while 100% of the households harvest buckwheat the whole plant. Finger millet and buckwheat are commonly harvested by hand knife or sickle while barley is harvested by hand knife, pulling spikes with two sticks '*khrip*' and by hand.

Buckwheat, barley and finger millet are threshed predominantly using traditional methods; flail, feet, and ox. However, 50% of the households thresh barley using a machine (Fig. 1). Of the traditional methods, flail '*Kubji/yarjung*' (made of two sticks joined by a knob, one for handle and the other swirl in the clockwise direction) is common while few use feet or ox.

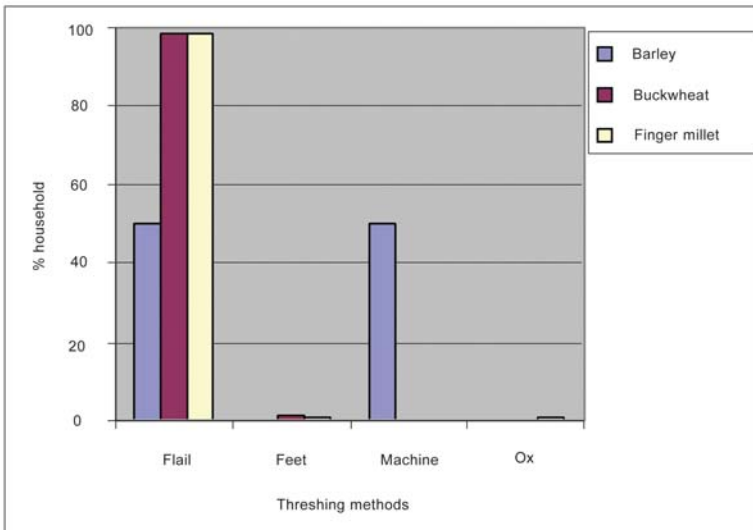


Figure 1: Percentage households using different threshing methods

Harvesting and threshing of buckwheat is carried out simultaneously especially in eastern Bhutan. In Bumthang Dzongkhag, buckwheat is commonly tied into bundles after harvest and left in the field for few days depending on the weather conditions until the crops are ready for threshing. Threshing of buckwheat is carried out in a seated or standing position usually with 'Y' shaped flail '*Jukpang*'.

Barley and finger millet spikes are stored in the attics, sacks or baskets and threshed as and when required in small quantities or in bulk. The spikes are usually dried in the sun or above the oven before threshing. In most parts of Bhutan, threshing is done manually. Dried spikes are then threshed using a long flail called '*kubji/yarjung*' and small quantities are threshed in the wooden or stone mortar '*Lheu/Lu*'. In Bumthang Dzongkhag, barley is also threshed using a machine.

Post-Harvest

Significantly high proportions (98%) of the households dry their seeds in the sun or above the oven before or after threshing. It was reported that 11%, 6% and 4% of the households have storage problem on barley, finger millet and buckwheat respectively. However, no clear pattern of storage problem was observed between the AEZs. Over 30% of the households consume their harvests within a year and thus no storage problem was reported. About 46%, 34% and 17% reported that barley, buckwheat and finger millet can be stored for more than 3 years respectively. It was reported that finger millet can be stored without storage problem up to 10-12 years.

Irrespective of these crops, the grains are stored in the sacks, wooden boxes, baskets, tins and plastic containers. To alleviate the storage problem, about 4% of the households dry their grains in the sun or use bait/trap, close openings and crevices and use biological control (Cat, *Felis catus*) to control rodents. The remaining 3% who reported to have storage problem does not take any control measure.

Uses and Consumption Pattern

The cultivation, usage and consumption of buckwheat, barley and finger millet are deeply embedded in the farming systems, culture and rural life. These minor cereals are cultivated not only for consumption but also for brewing, feeding animals, seeds, other purposes such as income generation and barter with other commodities to meet multiple purposes of household requirement (Table 3). The result revealed slight variation in the consumption pattern between crops and AEZs. In general, buckwheat is predominantly consumed as food while substantial proportions of barley and finger millet are used for brewing purposes.

Table 3: Consumption pattern (%) of buckwheat, barley and finger millets in different AEZ.

AEZ	Consumed	Alcohol	Fed to animal	Seed	Other
Buckwheat					
High	54.2	9.6	19.8	15.9	0.7
Mid	59.7	20.3	1.8	12.7	5.7
Low	69.5	0.0	1.3	12.5	16.8
\bar{X}	61.1	9.9	7.6	13.7	7.7
Barley					
High	42.1	36.2	6.5	13.7	1.5
Mid	31.5	50	2.7	15	0.8
Low	0.0	0.0	0.0	0.0	0.0
\bar{X}	36.8	43.1	4.6	14.4	1.2
Finger millet					
High	52.5	36.2	4.5	4.7	2.1
Mid	37.9	49.1	1.0	7.8	4.2
Low	50.9	19.6	3.5	5.3	20.7
\bar{X}	47.1	35.0	3.0	5.9	9.0

Barley is consumed as *nabchi* (flour), *zaw* (puffed grains), *thukpa* (porridge), *tshegnang* (cooked grains) and used in making *torm* (religious cake). Buckwheat is consumed as *khule* (cake), *keptang* (flat bread), *putang* (noodles), *dengo* (cooked flour), *chetam* and *thukpa*. Finger millet is commonly consumed as *dengo* although some farmers prepare *keptang* and *thukpa*. These cereals are also used during religious rituals and ceremony as *druna* (mixture of grains).

Ara/bagnchang is deeply embedded in the culture of the people in the rural areas. It is a social item, used for entertaining guests and friends, during lochoe/Kangse (annual religious ceremony), rimdro (religious rituals) and commonly consumed after a day’s hard work. Ara is offered to Kenchosum (God) as duetse.

The age-old tradition of barter system is still practiced in the villages, though in relatively small percentage (<10%). Farmers barter barley with foxtail millet and maize, buckwheat with wheat, finger millet, maize and rice, and finger millet with buckwheat, maize and rice. Some quantities of buckwheat, barley and finger millet are sold to generate income. About 11% sells buckwheat, 1% sells barley and 11% sells finger millet at an average price of Nu.8/Kg, Nu.11/Kg and Nu.7/Kg respectively.

Straw is fed to livestock, used as bedding for livestock, used for making compost or left in the field or burned (Fig. 2: a, b, c). Buckwheat and finger millet straw is primarily used for feeding livestock while only about 11% use barley straw for this purpose. The majorities of the farmers leave barley straw in the field to rot or burned to provide nutrients.

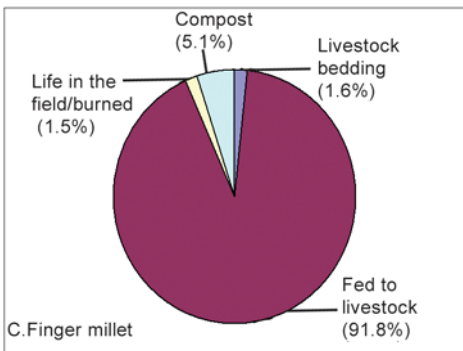
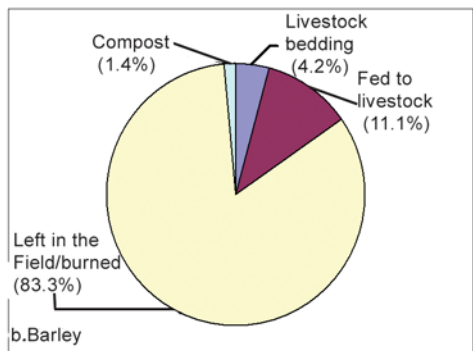
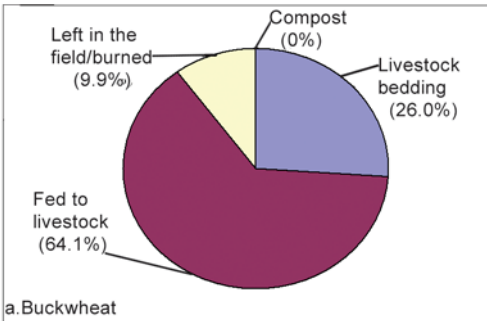


Figure 2: Uses of buckwheat (a), barley (b) and finger millet (c) straws by percentage household

Cropping Trend

Farmers have mixed opinions on the cultivation trend of buckwheat, barley and finger millet during the last 10 years. According to the farmers, 56%, 33% and 36% of the households reported a decrease in the cultivation of buckwheat, barley and finger millet respectively.

Some farmers perceive that buckwheat, barley and finger millet cultivation during the last 10 years have increased due to the increase in yields (due to fertilizer application), less labour required (no tillage for potato-base cultivation of buckwheat) and increase in population. On the other hand about 42% perceive that the cultivation of these crops have decreased due to; wild animal damage, government restriction of tseri (shifting cultivation), shift in food habit, replaced by commercial crops (potato), soil degradation, low yield and labour shortage. Since traditional varieties are of low yield and thus, poor net return, many farmers are interested in growing high yielding improved varieties of buckwheat (89%), barley (90%) and finger millet (92%) respectively.

Constraints

Diseases, insects, weeds and wild animals were reported as some of the biotic constraints in minor cereal production. Wild animals are the biggest problems followed by weeds. Insects and diseases affect crop production but they are not a major threat to minor cereal cultivation. No diseases were reported on buckwheat. Rust (*Puccinia* spp.) and loose smut (*Ustilago nuda*) diseases on barley, and blast (*Pyricularia grisea*) on finger millet were reported. Barley smut is controlled through rouging of infected plants while some farmers apply fungicides for rust. Generally, farmers ignore finger millet blast though some farmers rogue off infected plants.

Insects appear to occur slightly more on barley and buckwheat compared to finger millet. Although substantial percentage (<31%) of farmers reported insect problems, less than 7% take control measures. Aphids and caterpillar in barley, green beetles in buckwheat and stem borer (*Chilo partellus*) in finger millet were reported. Aphids and caterpillar in barley occur from vegetative to maturing stage. Green beetles in buckwheat attack grains at grain filling stage while stem borer in finger millet occur from vegetative to maturing stage. Generally farmers ignore the insect pest problem, only a few farmers apply insecticides and some farmers conduct religious rituals 'Jensek/lhabsang' and apply ash to control insects.

Pennycress (*Thlaspi arvense*), *Persicaria* spp., *Rumex* spp. and wild oat (*Avena* spp.) occur in barley fields while *Eleusine indica*, *Aegeratum conzoides*, *Digitaria*

ciliaris, *Cynodon dactylon*, and *Aegeratum* spp. are some of the common major weeds of finger millet. No systematic weeding is carried out in buckwheat since weed is not a major problem. However, 2-3 hand weedings are carried out for barley and finger millet.

A range of wild animal problems such as wild boar (*Sus scrofa*), sambar deer (*Cervus unicolor*), barking deer (*Muntiacus muntjak*), bear (*Ursus thibetanus*), porcupine (*Hystrix idica*), monkey (*Macca mulata*), birds and rodents were reported. Farmers commonly protect their crops from wild animals by guarding the field constantly, fencing, using trap/snare and slashing of bushes around the field. Buckwheat appears to be damaged relatively more by wild animals as compared to barley and finger millet.

Net Return

Buckwheat, barley and finger millet are grown with little or no fertilizer inputs. Low inputs, compounded by low yielding traditional varieties and wild animal damage result poor yield. The average yield of sweet buckwheat, bitter buckwheat, barley and finger millet are 0.71, 1.0, 0.98 and 1.21 t/ha respectively.

Yield differences were observed between the AEZs. The yield of sweet buckwheat is highest in high AEZ, followed by mid and low AEZ respectively. Conversely, higher yield of bitter buckwheat is harvested in mid than high AEZ. Although higher yield of barley is obtained in high AEZ compared to mid AEZ, no substantial difference was observed. Finger millet yield is lowest in high AEZ, higher on mid and highest in low AEZ respectively.

Owing to the high labour cost of Nu.63/day, over 82% of the total expenditures for the cultivation of buckwheat, barley and finger millet are incurred for labour. With high expenditure and low yield, economically it is not encouraging for farmers to cultivate these crops. Farmers obtain a net return of Nu.2258, 1982 and Nu.156 from barley, buckwheat and finger millet respectively. The net return calculated is excluding the enormous time spent by the farmers in guarding their fields against the wild animals.

Food Security

Buckwheat and barley are predominantly grown in high AEZ, 61% and 82% of the households cultivate buckwheat and barley respectively while finger millet is predominantly grown in mid AEZ (56%). Farmers have also rate these cereals high

in terms of food security in areas where they are predominantly grown. In general, farmers have rated these cereals medium in importance for food security, 58%, 55% and 77% for buckwheat, barley and finger millet respectively. Buckwheat and barley are staple food in high AEZ while in mid and low AEZ they are consumed as supplement to rice and maize. Finger millet is largely consumed as supplement to rice and maize and also used for brewing purposes. More importantly, these minor cereals substitute other cereals and fill the gap during the lean period from March-June when the previous stock is exhausted and next crop is yet to harvest. In general, minor cereals were rated as medium in importance for household food security.

DISCUSSION

Climate and Cropping Patterns

In higher elevations (high AEZ), the growing season is limited at both ends by cold temperatures, while in lower elevations (low AEZ) temperatures remain favourable for crop cultivation in winter.

Manures are commonly applied in the permanent fields but not in the shifting cultivation systems. Buckwheat a short duration crop is cultivated as first or second crop during the drier parts of the year in mid and low AEZ. Cultivating buckwheat in the wetland as a second crop not only utilises the residual moisture but also avoids drought, since the later buckwheat is planted, the faster it will mature (Myers, 2002). Finger millet is transplanted in summer coinciding with the rainy season, as it thrives well in moist condition. In high AEZ, buckwheat is cultivated as a main crop or after potato. Cultivating buckwheat after the potato can benefit from the residual nutrients, saves labour (zero-tillage) and it can be harvested before the onset of frost.

Over 95% of the households cultivate winter barley while only about 5% cultivate spring barley. This is because during the normal cropping season, best lands are used for preferred or elite crops such as potato, rice or maize. Further, it is cultivated during the drier parts of the year as winter barley is considered as the most drought tolerant of any other cereal (Nilan & Ulrich, 1993). Cultivation of winter barley also keeps farmers engaged during off-season.

Farmers have mixed perceptions on the cropping trend of minor cereals during the last 10 years. However, anecdotal evidence indicates a decline in the cropping of minor cereals. Problems associated with crop cultivation are perceived to be a major factor contributing to the changes in cropping pattern. Wild boar is the

biggest menace to the farming community. The general crop loss of up to 18% due to wild boar was reported despite the 24-hour and season round vigilance (MoA, 2001). Due to the constant wild animal problem, farmers stop growing crops and engage in non-farm activities. Farmers also migrate to the towns and cities, which results in the shortage of labour around the rural areas. Labour shortage problem is expected to get worse in future as more children go to school.

Inadequate processing facilities, less creativity of processing products, lack of adequate coordination in marketing the products, low yield of landraces and lack of high yielding improved varieties are some of the major contributing factors that encourage farmers to opt for other crops that have commercial values. In Bumthang, a significant percentage of households have reported that there is a decrease in buckwheat and barley cultivation due to the replacement by a commercial crop, potato. Conversely, potato cultivation, however, is not perceived to affect buckwheat and barley cultivation since these crops can be grown in rotation or as potato-base. Therefore, potato cultivation can enhance cultivation of these crops.

Farming Practices, Production Constraints and Economic Return

In the high AEZ, animal manure is most commonly applied as FYM, while FYM and tethering are used in mid AEZ and tethering in low AEZ. This difference is attributed to the weather conditions, wherein in high AEZ it is too cold for animals to be tethered in the field. In warmer mid and low AEZs, animals can be tethered outside almost all year.

The use of fertilizer is limited to high AEZ, although some farmers apply urea as a top dress on finger millet nursery in low AEZ. This trend can be either due to the importance of the crop in a particular AEZ or related to socio-economic development. Although, more farmers apply fertilizer with increase in income, as reported by Norbu and Roder (2000), animal manure will continue to be the major source of plant nutrients and organic matter in the Bhutanese farming systems.

Barley receives more FYM (3.6 t/ha) than buckwheat (0.9 t/ha) and finger millet (1.3 t/ha) respectively. This is co-related to the cultivation of crops under different land types. Barley is cultivated in the dry land where FYM is commonly applied while buckwheat and finger millet are cultivated in shifting cultivation system where no FYM is applied. Animal manure is not applied in the shifting cultivation system because burning of organic matter in shifting cultivation provides nutrients such as Calcium, Magnesium and Phosphorous (Lal & Stewart, 1995).

Buckwheat, barley and finger millet are harvested and threshed manually. Small land holdings, rugged terrain and land fragmentation are the major challenges to mechanisation. Land fragmentation is likely to get worse as children inherit the land from their parents and divide among the siblings. Although substantial percentage of farmers in Bumthang Dzongkhag (district) thresh barley using machine, manual harvesting and threshing will continue to be the predominant practice.

Sweet buckwheat yield decreases with decrease in altitude. Buckwheat is a temperate, long-day crop well adapted to cooler conditions. High temperatures in lower elevations during blooming cause sparse seed set (Wolfe & Kipps, 1953). Generally, buckwheat in mid and low AEZ is cultivated as first or a second crop.

The later the crop is planted, faster it matures due to shortening days (Myers, 2002). The shorter duration to maturity lowers yield due to lower nutrient uptake and dry matter accumulation. The yield of bitter buckwheat in mid AEZ is slightly higher than in high AEZ. However, the difference is not substantial. It indicates that bitter buckwheat is adapted to wider environmental conditions compared to sweet buckwheat.

The yield of sweet buckwheat is lower than the bitter buckwheat, because it is a cross pollinating crop with low fruit set, 10-12% (Edwardson, 1996). Bitter buckwheat, on the other hand is self-pollinating and the fruit set is high. The on-station trials at RNRRC-Jakar in 2003, found out an average of 540 filled seeds per plant in bitter buckwheat and 140 filled seeds in sweet buckwheat respectively. The percentage sterility was higher in sweet buckwheat (42%) than bitter buckwheat (30%). Low yield of buckwheat is attributed to high percentage sterility and lodging problem.

Barley yield decreases with decrease in altitude. It is because barley is adapted to cooler growing season in the higher elevations (Nilan & Ullrich, 1993). Although, barley is successfully grown in low input system, there is a potential to increase the yield through increasing inputs.

Finger millet yield decreases with increase in altitude. Finger millet is a tropical, short-day plant (Purseglove, 1976), well adapted to warmer temperatures. Temperature is higher in lower elevations than in higher elevations, thus, favouring the crop development in lower altitudes.

Diseases, insects, weeds and wild animals were reported as the major biotic constraints in crop production. These problems are common across the country, and therefore do not vary between AEZ. No disease problem was reported on buckwheat. This evidence indicates that either pathogen population is very low to cause significant damage or buckwheat is resistant to diseases. Further, buckwheat

cultivation in the shifting system reduces the build up of pest population. However, it is imperative that disease incidence is monitored regularly.

Buckwheat grows rapidly and out-competes weeds (Myers, 2002), thus no major weed problem was reported. However, weed problem was reported on barley and finger millet. It is reported that farmers carry out 2-3 hand weedings to control the weeds. Although, herbicides such as butachlor, glyphosate and metribuzin are available, herbicides are hardly used. Herbicides may be expensive for farmers and may not be feasible under subsistence farming. Hand weeding may be laborious, yet it appears to be the best available options under subsistence farming system. In order to control weeds, finger millet should be transplanted as transplantation reduces weed problem (Rachie & Peters, 1977) and obtain higher yield than direct seeded (Sthapit *et al.*, 1994).

Farmers have rated wild animals as the biggest problem in farming. Percentage households who reported to have wild animal problem was higher on buckwheat than barley and finger millet. Scattered farms and farms located near the forests are more vulnerable to animal damage. Buckwheat is more vulnerable to animal damage as they are cultivated in grassland shifting cultivation system, away from permanent fields. The preventive measures are very conventional. Over 68% of the households guard the field, day and night from the day of sowing till harvest, beating tins, shouting and going round the field. This takes up a lot of time and causes drudgery.

The net returns were calculated from the costs incurred for land preparation to harvesting and threshing. The time spent by the farmers in guarding against wild animals and birds were not taken into account. Some of the major challenges to profitable production are high labour cost, low yield potential of landraces and wild animal damage. Despite these challenges and low external inputs, cultivation of minor cereals is still profitable though the net return is low. Straws are valuable as fodder for animals but their values are often not considered in monetary terms. Therefore, much more than just the monetary values, these crops serve multiple purposes and are crucial in the farming systems.

Minor Cereals, Food Security and Future Potential

In the past, buckwheat was perceived as a food for the highlanders. Today, Bumthang's *khule* and *puta* are the delicacies for the Bhutanese. It is not uncommon for visitors to have *khule* and *puta* in their menu while visiting Bumthang. Buckwheat is nutritious and it is good for diabetic patient and blood pressure (Bonafaccia & Fabjan, 2003). Therefore, as socio-economy progresses and more people are cautious about their diet, buckwheat with high nutritional quality and medicinal benefits has good future market potential.

Barley is most commonly consumed as *nabchi* (flour). In the past when rice was less accessible, people especially in eastern Bhutan used to consume it as *tshegnang* (cooked grains). However, this tradition appears to be disappearing due to a shift in food habit, with more people wanting to eat rice. Although barley contains minerals, proteins, fibres and beta-glucans (Bonafaccia & Fabjan, 2003), it is less palatable and cannot be used for baking as it lacks gluten. However, barley will continue to be an important source of food in the marginal areas.

Finger millet will continue to be the source of food and a material for brewing *ara/bangchang*, which is inevitable in the rural areas. Farmers also generate some income, especially during emergency, by selling small quantities of *ara/bangchang*. The money earned is used for purchasing multiple household requirements, thus, contributing to food security. However, as suggested by Pradhan *et al.* (2002) product development and promotion need to be explored to diversify uses and encourage cultivation.

Over 64% feed buckwheat straw to animals, which is valuable as winter-feed, particularly in the high AEZ. Only about 11% of the barley straw is fed to animals since it is less palatable. It may also have less nutritional value as over-mature grasses can have a zero or even negative value as feed (Schiere *et al.*, 2004). Over 91% of finger millet straw is fed to animals. It contains more leaves and is thus more digestible. According to Schiere *et al.* (2004), leaves have a higher digestibility and protein concentration than do stems, while leafiness may be associated with increased stem digestibility.

Although, buckwheat, barley and millets contribute only 7.9% of the total cereal production to the national food basket (MoA, 2002a), it is imperative to understand their role in diversifying crop production, Bhutanese diet, household food self-sufficiency and food security. Despite the preference for rice, buckwheat and barley are the staples in the high AEZ and marginal areas where these are the only grain crops (Roder & Gurung, 1990). Minor cereals supplement rice and maize, substitute other cereals and fill the gap during the lean period from March-June when previous stock is exhausted and before next crop is harvested, thus avoiding risk of food insecurity. Therefore, these crops are vital for household food self-sufficiency and food security, particularly for the subsistence farmers in the marginal areas.

Farmers particularly in high AEZ generate income from potatoes. However, promoting potato as a monoculture can result uncertain food security, especially in view of the late blight caused by *Phytophthora infestans*. Cultivation of minor cereals diversifies crop production. Diversity allows crop rotation, which interrupt disease and weed growth cycles (Stevenson *et al.*, 1998). Crop rotation also reduces complete loss of a crop to wild animals since the community in one location grows

same crop. Given the limited options for other crops due to biophysical limitations and irregular or unstable non-farm employment, minor cereals are perceived as the stable source of food in the marginal areas.

The markets and marketing strategies for buckwheat need to be explored both within and outside the country. Through proper coordination, buckwheat flour can be marketed to the hoteliers in Thimphu and other major towns and cities where people are craving for *khule* and *puta*. The market potential of buckwheat is clear from the scenario that people travelling from Bumthang or buckwheat growing areas take buckwheat flour as souvenir for their friends and relatives dwelling in the cities. Therefore, the buckwheat market appears to have good prospects in the future.

There is a potential for high altitude spring malting barley production in Bumthang Dzongkhag. Three exotic spring malting barley varieties; Otis, Marina and Dan Yanka are fairly tolerant to rust (*Puccinia* spp.) and are in pipeline for release. The products can be sold to the local breweries, Red Panda Brewery and Army Welfare Project who are importing raw materials from India, although price competition needs consideration. There is also a plan of establishing a new brewery in Bumthang with an annual capacity of 200,000 litres (MTI, 2001) in the near future. Therefore, barley is seen as an alternative cash crop.

CONCLUSION

Climate affects crop distribution, growing season and cropping pattern. Short growing season in the high AEZ does not favour sequential or relay cropping unlike in the lower elevations. However, winter crops such as barley and wheat that require vernalization can be cultivated during the cold winters. In the low AEZ, main crops or crops that require more water can be grown during the rainy season and short duration crop such as buckwheat can be cultivated either as first or second crop during the drier parts of the year.

No improved varieties of buckwheat and barley are available except for finger millet. It appears that only limited germplasm of buckwheat, barley and finger millet are available. Therefore, there is limited opportunity for increasing production and very less opportunity of diversifying cultivation practices. More varieties with different maturing periods, adaptation to different climatic and soil conditions, and possessing different qualities are required.

Soil fertility is predominantly maintained through application of animal manure in the form of FYM or tethering of animals in the field. These practices are well established in the traditional farming systems and do not involve cash payment. On the other hand, fertilizers require cash payment and may not be easily accessible in right amount and on right time. Fertilizer use may increase with socio-economic

development but animal manure will continue to be the major source of nutrients in the Bhutanese farming systems.

The evidence indicates a decline in shifting cultivation practices. With increase in population, land fragmentation is perceived to continue, fallow period will decrease and crop intensification is expected to take place. With increasing pressure on the land and agriculture gradually shifting from subsistence to semi-commercial system, shifting cultivation is expected to decline and be replaced with permanent cultivation system.

Field preparation, sowing, transplanting, harvesting and threshing are carried out manually using traditional methods. Rugged terrain remains a major stumbling block to mechanisation. Mechanization is perceived to ease labour shortage problem to a certain extent but mechanization may be not feasible in large parts of Bhutan and therefore, traditional methods of farming may continue in large parts of the country.

Diseases, insects, weeds and wild animals were identified as some of the biotic constraints for minor cereal cultivation. Insect pests and diseases do not appear to be economically important at present. However, constant monitoring may be required. Although hand weeding is labour intensive, it appears to be the best option under subsistence farming systems. Wild animals are rated as the most important pest problem. Unless the present Act on wild animal protection is amended, wild animal problem is likely to continue for some years.

Minor cereals are important for household food self-sufficiency and food security, supplement rice and maize, substitute other cereals and fill the gap during the lean season when the previous harvest is exhausted and before next crop is harvested, thus avoiding risk of food insecurity. These crops are vital in the Bhutanese farming systems and expected to continue as a source of food in the marginal areas where other options are limited. However, introduction or innovation of processing technology, product development and promotion is necessary to encourage and sustain cultivation of minor cereals.

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Rainfed Lowland Rice Cultivation in Bhutan: A Survey Report

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ABSTRACT

This study reports on the rice cultivation practices under rainfed environment in Bhutan based on a rapid farm survey conducted in 2003. Although rainfed lowland rice system accounts for major portion of rice growing area, it contributes least in terms of production due to uncertainty of irrigation water, soil fertility and pest problems. About 33 traditional or introduced local varieties are cultivated by farmers. Traditional varieties are characteristically white preferred for their taste but are susceptible to diseases. About 17 local varieties are reported to be lost. Mean yield of rough rice is estimated at 680 kg/acre. The rate of adoption of improved varieties is about 44%. Use of chemical fertilizers is limited to 13.2% and tethering is the common practice of manure application. Adoption of the use of herbicides and pesticides is low. Weed, diseases and pests are major problem in rainfed rice ecosystem and estimated to reduce 2-50% of total yield. Vertebrate pest, especially elephant, is a nuisance in rice crop, often destroying the crop completely. Storage losses due to rodents, weevils and grain moth are estimated at 2-50% of total production. Approximately, 97 men-days of labor are required to carry out various cultural operations. An additional labor of 60 men-days per season is spent in guarding the crop against vertebrate pest. Recommendations include evaluation of suitable varieties for the rainfed ecosystem together with component technologies, better soil and pest management and the use of labour-saving technologies.

KEYWORDS: Rainfed rice, rainfed rice environments, local varieties, pests, storage losses

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INTRODUCTION

Rice is a major crop of the Wet Subtropical (WST) zone, which accounts for about 40% of the total rice area in Bhutan. But from the productivity point of view, it is the least productive of all agro ecological zones (AEZ) with an average yield of less than 2t/ha. The low yield is primarily attributed to the poor soil conditions, high disease and pest incidences, and above all, unreliable irrigation supply (9th FYP Strategy Document). The above inverse relation of area and productivity offers an opportunity to raise the production in WST even with slight increase in the current yield level. The WST zone is characterized by long but erratic rainy season where drought frequently occurs in mid season. Hence, the rice crop in this AEZ is grown partially or completely under rainfed conditions.

The rice research attempts in the past have focused on improvements of rice under favourable conditions, i.e. irrigated environments, of high and mid altitudes. Several high yielding varieties and appropriate technology packages have been released for different agro-ecological zones. Despite much progress in rice research and development, rainfed rice received very limited attention till date. No conscious efforts were made in improving production of rice of the unfavorable condition. Even the varieties released for similar altitudes could make little difference in productivity because the breeding attempts were targeted on irrigated environments and were constrained by the lack of clear understanding of rainfed environment. Thus a national level study to capture the production system of rice under lowland rainfed conditions was warranted.

Objectives of the Study

Briefly, the main objectives of this survey are:

- To understand cultivation/farming practices of lowland rainfed rice
- To study production trend and future potentials of rainfed rice
- To identify production constraints and needs for research interventions
- To aid in developing strategies to improve rice production in rainfed environments

Rainfed Rice Environments

A precise definition in scientific terms for the rainfed rice environment in Bhutan is yet to be developed. However, for the purpose of this study the rainfed rice environment is defined as “*a target population of environment where rice fields are naturally flooded and there is limited control over irrigation water. Rice is often direct seeded or transplanted when rain intensifies and the soil surface may be flooded during part of crop cycle*”.

By definition, the proposed rainfed environment under study is devoid of any controlled water supply and the crop is dominantly controlled by seasonal rainfall. Rainfed ecosystem in this context covers both *upland* and *lowland* unfavorable conditions (IRRI 1984 & Mackill *et al* 1996). Upland suggests that the rice is grown in dry fields that are not flooded whereas lowlands are terraced and flooded. The main difference between lowland and upland rainfed rice is that the lowland type is grown in banded terraces where water is collected and impounded, whereas upland rice is grown in dryland without rice terraces/bunds just like maize or other non-irrigated crops.

In our context lowland rainfed rice is similar to irrigated rice, the main difference being the source of irrigation water; rainfed rice depends completely on the amount of rainfall received in the crop season and does not have perennial round-the-year source of irrigation water. Thus this study was focused on areas where irrigation control was absent, or where there was no assured source of irrigation and rice cultivation depends completely on rainfall or monsoon.

METHODOLOGY

Sampling Method and Sample Size

The sites sampled were Sarpang and Samtse, two potential rainfed lowland rice growing Dzongkhag in Bhutan. From each Dzongkhag three representative sample geogs, identified as potential rainfed lowland rice growing areas were selected through consultation with the concerned Dzongkhag Agriculture Officers (DAOs). Potential pockets/villages of the study were then selected with the help of DAOs and extension staff. Stratified random samplings of households were done from each village in order to cover all possible altitude range of the sample geog. The attempt was to select at least 10 households per geog and obtain substantially comfortable sample size.

Sampled House Hold Category Distribution by Geogs and Altitude Ranges

A total of 76 farming households (Table 1) were surveyed from two selected Dzongkhags. Of the total, 46.1 % of households (n=35) were from Sarpang and 53.9 % house holds (n=41) from Samtse Dzongkhag, which exhibits a good proportion of sample distribution on either sites.

Table 1: Distribution of households and altitude range within geogs

	Geogs						Total
	G/phu	J/cling	U/ling	G/ney	S/soo	C/mari	
No. of selected household	10	15	10	15	13	13	76
Altitude (m.asl)	300-350	1260- 1450	350- 400	500-570	500-890	400-1800	300-1800

Data Processing and Analysis

Informal question and answer were done with individual farmer with the pre-set questionnaire. Data obtained were crossed checked in the field itself. MS excel was used for database and crossed checked which than was transferred to SPSS software (version 11.0) for analysis. Tools such as cross tabulations, frequency and ANOVA were used for analysis and interpretation of the results.

RESULTS

Bio-Physical Environment

Rainfall

The rainy season starts by early June and ends by early September (Table 2), with average rainfall duration of four months across the study sites. On an average, the region receives 13 ± 4 days of rainfall/month through out the rainy season (range of 10-23 days rainfall/month). The highest rainfall is received during mid July-mid August, with an average of 20 ± 4 days of rainfall per month (Table 3).

Table 2: Percent of respondents for the start and end of rainy season by geog

Geog	Start		End	
	June	Late June	August	Early Sept.
Gelephu	3.9	9.2	2	8
Jigmecholing	6.6	13.2	10	5
Umling	10.5	2.6	0	10
Ghumauney	9.2	10.5	8	7
Sibsoo	13.2	3.9	10	3
Changmari	9.2	7.9	9	4
Nos. of respondents	40	36	39	37
Total	76		76	

Table 3: Mean of average (days) monthly rainfall and peak rainfall (days) by geogs

Geog	Average days of monthly rainfall	Days of rainfall during peak month
Gelephu	13.7 ± 1.3	20.7 ± 1.4
Jigmecholing	12.4 ± 1.1	18.8 ± 0.9
Umling	10.8 ± 0.5	18.5 ± 0.7
Ghumauney	14.5 ± 1.1	20.7 ± 0.9
Sibsoo	14.9 ± 1.3	21.1 ± 0.9
Changmari	13.3 ± 0.7	20.3 ± 1.1
Total	13.0 ± 0.4	20.0 ± 0.4

Landscape and Topography

The type of landscape (Table 4) is from gently undulating to steep for the rainfed rice field. A total of 59.2 % of the respondents cultivated rice in plain or gentle slopes and, 23.7 % of respondents in gently undulating areas. Few cases of rice fields with steep topography (>30°) were observed.

Table 4: Percent of respondents for topography/slope of their rice field by geogs

Topography	Geogs						
	G/phu	J/choling	Umling	G/ney	Sibsoo	C/mari	Total
Gentle slope (<10)	10.5	3.9	5.3	18.4	11.8	9.2	59.2
Gently undulating (10-15°)	2.6	1.3	6.6	1.3	5.3	6.6	23.7
Undulating (15-20°)	0	6.6	1.3	0	0	0	7.9
Steep (20-30°)	0	7.9	0	0	0	1.3	9.2
Tota	13.2	19.7	13.2	19.7	17.1	17.1	100

Soil

From the results in Table 5, the percent of response (data based on response from farmers and visual observation by interviewers) for the type of rainfed rice soil are 39.4 % fine clay, 32.4 % sandy loam, 25.4% clay loam and 2.8 % of coarse sandy soil. Of all, brown- reddish clay soils dominate the rice pedology in the region followed by grayish-black sandy loam soils.

Table 5: Percent of respondents for type of soil in the rice field by geogs

Soil type	Geog						Total
	G/phu	J/choling	Umling	G/ney	S/soo	C/mari	
Fine clay	-	11.3	8.5	8.5	4.2	7.0	39.4
Clay loam	4.2	4.2	-	8.5	2.8	5.6	25.4
Sandy loam	8.5	5.6	1.4	4.2	7.0	5.6	32.4
Coarse sandy	1.4	-	-	-	1.4	-	2.8
Nos. of respondent	10	15	7	15	11	13	71

Area and land use pattern

The exact acreage under rainfed rice area cannot be stated as no such work has been done in the past due to lack of clear cut delineation between irrigated and rainfed rice systems. However, the major portion of the WST rice zone comprises of rainfed lowland rice, which accounts for 40% of the total rice area. Based on the estimates from the collected data, rice environment ranged from 300 to 1800 m above sea level (masl). On an average, an area of 5.08 ± 0.48 (Table 6) acres/household is under cultivation from which rainfed rice cultivation accounts for 58.2 ± 27.4 % of the total, i.e, approximately an average of 2.61 ± 0.19 acres per household. Rice cultivation under assured irrigation is as low as 0.44 ± 0.13 acres/household.

Table 6: Mean area (acres) of land use pattern with in the geog.

Geog	Total land holding	Total cultivated land	Total rice area	Rainfed rice area	Rice under assured irrigation
Gelephu	5.30 ± 0.34	4.34 ± 0.12	2.93 ± 0.27	2.58 ± 0.43	$.33 \pm 0.33$
Jigmecholing	8.63 ± 1.75	6.77 ± 1.30	3.45 ± 0.39	3.65 ± 0.48	$.70 \pm 0.37$
Umling	5.00 ± 0.00	3.60 ± 0.40	2.67 ± 0.26	2.21 ± 0.33	$.15 \pm 0.15$
Ghumauney	5.80 ± 0.85	4.15 ± 0.65	2.58 ± 0.48	2.50 ± 0.51	$.07 \pm 0.06$
Sibsoo	5.88 ± 0.57	4.49 ± 0.84	2.77 ± 0.37	2.55 ± 0.39	$.62 \pm 0.38$
Changmari	7.89 ± 1.69	5.37 ± 1.54	2.62 ± 0.34	2.01 ± 0.41	$.70 \pm 0.40$
Total	6.52 ± 0.50	5.08 ± 0.48	2.87 ± 0.15	2.61 ± 0.19	$.44 \pm 0.13$
No. of respondents	66	58	70	61	76

Cropping pattern

In the lowland conditions, the land is mostly left fallow after the single rice crop. However, in areas where there is adequate monsoon rain, rice-maize and rice wheat are the predominant cropping patterns. Rice is planted in early June-July and harvested in late October-November. To take advantage of the residual moisture from the soil, farmers sow maize or wheat or potato immediately after harvesting rice in November. In the uplands, mustard, barley, buckwheat and vegetables (radish, turnip and spinach) are planted in December and harvested in March-April (Fig 1). Some practices of second maize crop during the month of March to June are also prevalent in some pockets.

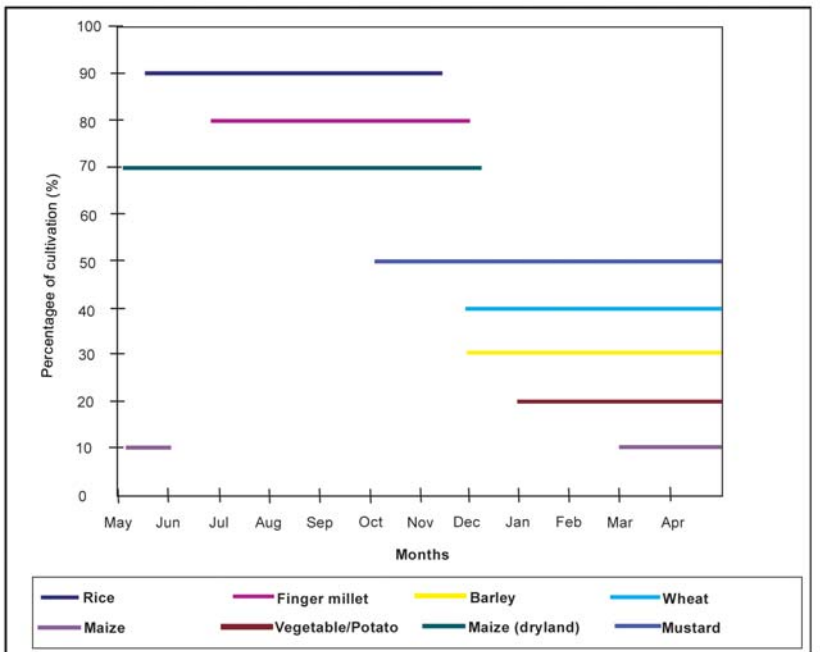


Figure 1. Major cropping patterns under rainfed eco-system

Cultivated local varieties

A total of 33 local varieties are reported being cultivated presently, fourteen of which are exclusively cultivated in Samtse Dzongkhag and two varieties, Attey and Choti Masino, cut across Sarpang Dzongkhag also. A total of nine varieties are presently cultivated at Sarpang Dzongkhag. Choti Masino, Jasuwa, Babu

Jasuwa, Kalo Noonua, Chotakati and Mansara are major varieties cultivated by the farmers of Samtse Dzongkhag. In Sarpang, Choti Masino, Mama and Mauli are some of the widely cultivated varieties in the Dzongkhag.

Cultivated local varieties are almost all white pericarp varieties, generally of good taste and some scented. Most varieties are easy to thresh, some even reporting shattering loss in the field in case of ‘very easy’ to thresh cultivars. Most landraces of this environment are prone to lodging, and susceptible to diseases and pests.

Over the last decade or two, farmers reported to have cultivated many varieties in addition to the existing ones. Today, about 17 landraces are either lost or are on threat of being lost forever. Various reasons were given for discontinuing a particular variety, of which the low yield characteristics, stands out to be the major factor. Seed quality deterioration and late and non-uniform maturity are next important reasons, both contributing equally to the genetic loss/erosio.

Modern varieties

BR 153 commonly cultivated improved modern variety; accounting for 69.7% of the total cultivated improved modern varieties (IMVs) in the region, and is more widely cultivated in Sarpang Dzongkhag. In Samtse Dzongkhag, both IR 8 and BR 153 are commonly cultivated IMVs, adopted in equal proportion. Other IMVs like Bajo Kaap, IR64, Pusa 33 and TMVs (traditional modern varieties), Bikashi are also being cultivated by some farmers (Table 7).

Table 7: Percent of respondent cultivating different modern varieties by geogs

Modern variety	Geog					Total
	G/phu	U/ling	G/ney	S/soo	C/mari	
BR 153	24.2	30.3	-	9.1	6.1	69.7
IR64	-	-	3.0	-	-	3.0
Bajo Kaaps	-	-	6.1	-	-	6.1
Bikashi	-	-	-	3.0	-	3.0
IR 8	-	-	-	6.1	9.1	15.2
Pusa 33	-	-	-	-	3.0	3.0
Nos. of respondents (n)	8	10	3	6	6	100 n=33

Table 8 shows the average yield gap between modern and traditional rice varieties in Sarpang and Samtse Dzongkhags. The average yield of modern varieties (MVs) in Sarpang is 690 kg/acre, whereas the average yield of traditional varieties (TVs) is reported to be 537 kg/acre. In Samtse Dzongkhag, the average yield of MVs is 823 kg/acre and that of TVs is 668 kg/acre. Generally, traditional varieties are lower yielding than cultivated modern varieties across the rainfed environment with an average yield gap of 153 kg/acre.

Table 8: Average yield (kg/acre) of traditional and modern varieties in Sarpang and Samtse Dzongkhags

Dzongkhag	Av. yield of traditional varieties	Av. yield of modern varieties	Yield gap
Sarpang	537	690	153.3
Samtse	668	823	154.5
Average	603	756.5	153.5
Overall average yield	680		

CONSTRAINTS TO ADOPTION OF MODERN VARIETIES AND THEIR COMPONENT TECHNOLOGIES

Adoption of Modern Varieties

Approximately 44% of the households have registered the adoption of MVs in Sarpang and Samtse dzongkhag from which 15.6% cultivate solely modern varieties. However, major chunk of the households (56%) in the survey region have not adopted the modern varieties, which could be the main reason for the lower productivity of rice in the area. Even among the adopters, the acreage of modern varieties cultivated in a household is lower than that of local varieties.

Low adoption rate of IMVs could be attributed to the varietal characteristics of modern varieties and its preferences by farmers. Besides BR 153, cultivated modern varieties like IR 8 and IR 64 were those targeted for the favourable irrigated conditions, which however have been adopted by some farmers due to the proximity of targeted environment where the varieties were easily available through extension crop promotion programs.

These varieties yield low under low input conditions like fertilizers and irrigation and yield is generally unstable under drought conditions. Certain negative traits of MVs, like poor taste, difficulty in threshing, etc. (Table 9), are also perceived by farmers as factors affecting for its poor adoption.

Table 9: Summary of positive and negative traits of modern varieties by farmers

Varieties	Positive traits	Negative traits
BR 153	Moderate yield under high input/irrigated condition, Stable yield Early maturity Resistant to pest and diseases	Poor taste Bit hard to thresh Low milling recovery with more 'brokens'
IR 64	Resistant to lodging Resistant to pest and diseases	Low yield
Kaap 1 & 2	Resistant to lodging Resistant to pest and diseases	Unstable yield, Low yield Poor taste
Bikashi	Moderately resistance to drought	Poor taste, Hard to thresh
IR 8	Good yield in high input condition	Susceptible to diseases & pest Unstable yield, Succumbs to drought
Pusa 33	Resistant to lodging	Low yield

Manures and fertilizers

Cow dung compost or FYM is usually applied, by carrying it in the basket, in the field few weeks prior to land preparation. FYM application by carrying is limited to 23% (Table 10) of the total observation, whereas in-situ application by tethering is the principle practice followed through out the surveyed region. Tethering is usually done during fallow months, where second crop after rice is usually not cultivated.

Table 10: Percent of respondents for fym/cowdung compost application across geogs

Response	Geog						Total
	Changmari	Sibsoo	Ghuma- uney	Umling	Jigme choling	Gelephu	
Apply by carrying in baskets	30.8	23.1	33.3	0	20	25	3.0
Do not apply at all	23.1	23.1	46.7	100	20	12	6.5
Tethering	46.2	53.8	20.0	0	60	62	0.5

The use of synthetic fertilizer is very low. Only 13.2% (Table 11) of the total respondent reported the use of synthetic fertilizers whereas 86.8% still do not use chemical fertilizers. Urea and suphala are the common chemical fertilizers used by few farmers. The non-availability of chemical fertilizers or non-availability on time has emerged as the most important constraints to its adoption by farmers. Besides, farmers responded that high cost of fertilizers make their application unprofitable in the rainfed lowland ecosystem where the dependence on monsoon and inefficient water management techniques reduce the efficiency of chemical fertilizers. Besides, given the subsistence farming system of rainfed environment farmers do not afford to buy 'high-cost' fertilizers.

Table 11: Percent of respondents for use of synthetic fertilizers in rice crop

Chemical fertilizer use	Geog						Total
	G/phu	J/cling	U/ling	G/ney	S/soo	C/mari	
Yes	7.9	2.6	1.3	1.3	-	-	13.2
No	5.3	17.1	11.8	18.4	17.1	17.1	86.8
Nos. of response	10	15	10	15	13	13	76

CULTURAL OPERATIONS

Sowing

Sowing of rice in the survey region commences from late May and sometimes extends till late June when the monsoon rains are late. Sowing is either done with the first shower of rain or in dry fields. Seed is broadcasted evenly in the field and covered by light planking or by hand. On an average, the quantity of seed rate used is 26.5 ± 1.6 kg/acre, with significant differences with in geogs.

Transplanting

Transplanting is the principle crop establishment method employed in the rainfed system (97.4%). Direct seeding of rainfed is observed in only 2.6% (Table 12) of the total sample household, which is typical to Umling and Ghumauney geogs. Transplanting starts by early July and last till first week of August. The major source of water during this time is from the rainfall activated streams, springs and interflows. In many areas the volume of water is not adequate, since major transplanting coincides with the beginning of rainfall where the frequency is low and of less intense.

Table12: Percent responses for methods of crop establishment employed

Crop establishment method	Geogs						
	Gelephu	J/choling	Umling	G/ney	Sibsoo	C/mari	Total
Transplanting	13.2	19.7	11.8	18.4	17.1	17.1	97.4
Direct seeding	-	-	1.3	1.3	-	-	2.6
Nos. of respondents	10	15	10	15	13	13	100(n=76)

Harvesting and threshing

Harvesting is usually done by sickle after which the harvested bunch is left in the field to dry for few days (3-7 days). Threshing is often done in the field itself wherein dried bundles are threshed against stones (Fig 2) or wood (95%) or the bundles are threshed by beating with flail (4%).



Figure 2. Percent of different methods of threshing of rice

PRODUCTION CONSTRAINTS

Constraints in irrigation

About 22.8% (Table 13) of the total sample household has an assured irrigation through perennial source, wherein the conducting systems are either concrete or traditional mud canals. Approximately, 54.3% water sources are seasonal interflows and rainfall activated springs and roughly 22.9% of farmers depend directly on rainfall for transplanting.

Table 13: Percent respondents for source of irrigation by geogs

Source	Geog						Total
	Gelephu	J/choling	Umling	G/ney	Sibsoo	C/mari	
Perennial canals	4.3	1.4		2.9	1.4	1.4	11.4
Perennialrivers/ streams/springs	1.4	4.3		1.4	1.4	2.9	11.4
Rainfall activated sources/interflows	7.1	14.3	4.3	8.6	8.6	11.4	54.3
Direct rainfall	1.4	1.4	4.3	7.1	5.7	2.9	22.9
Total	14.3	21.4	8.6	20.0	17.1	18.6	100

Major problem of the existing discharge system of water in the study area is that the source is rainfall dependent, irregular and unreliable. Discharge rate is often low and discontinuous during the time of transplanting. In addition, heavy showers during peak season leads to frequent landslides, floods and wash-aways disrupting the continuity of water, both in seasonal and perennial irrigation system (Table 14), especially in traditional system.

Table 14: Percent respondent for major constraints in irrigation system

Problems in irrigation system	Dzongkhag		
	Sarpang	Samtse	Total
Less water volume & low discharge rate during transplanting	10.2	18.4	28.6
Damage of canals by landslides/ sinking area/erosion	18.4%	4.1	22.4
Irregular & erratic supply	16.3	32.7	49.0
Total	44.9	55.1	100

Drought stress

Drought has long been considered as the primary constraints to rainfed rice production. Similarly, the survey region is characterized by erratic rainfall pattern, often exposing the crop to drought during the critical stages, thereby adversely affecting the crop yield. Figure 3 shows the major rice growing seasons of rainfed lowland in Bhutan. The sowing season begins by late May when there is little or no rainfall due to which the sowing operation is hampered. Farmers have to stagger sowing operation till mid June while waiting for rain. This in turn delays the transplanting operation as a whole.

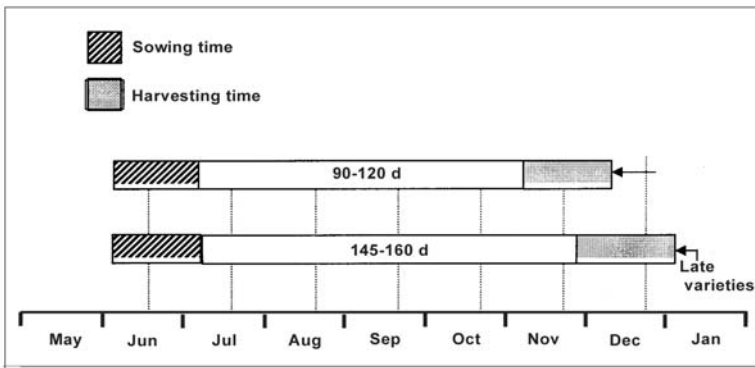


Figure 3: Rice Seasonal calendar

Rainfall season begins only by June, where as the sowing has to be carried out in late May, to synchronize transplanting with the probable monsoon rain in July. Hence, sowing is done either by dry bed or wet bed method.

As per farmers, the area often experiences dry weather extended for weeks, right after transplanting, resulting in hardening of puddled soil, exposing young plants to drought stress. Besides, drought condition also hits plants during critical stages such as tillering and flowering stage which is often manifested as low tiller numbers and too many empty panicles. A reliable and adequate meteorological data over the years, which could not be obtained during the survey, will be invaluable in future for proper understanding and analysis of the system. Developing drought escaping technologies and drought tolerant varieties will be an effective approach to address the drought stress.

Constraints in Weed Management

Weed is one of the major problems of rainfed rice system whereby the climatic condition favours vigorous weed growth. Of the total, 90% of respondents reported problems due to severe weed infestation in their rice field. Hand weeding is the major weed control measures employed and use of chemical herbicides, Butachlor, as a control means is limited to as low as 11.8% (Table 15). Non-availability and non-availability on time is the main reasons cited by farmers for limited use of chemical herbicide. Usually one to two hand weeding is carried out within two to three weeks after transplanting. The mean rate of application of Butachlor across two dzongkhags was 6.44 ± 4.2 kg/acre and rate of application widely differed from farmer to farmers. Approximately, 2-50% yield is reported to be reduced due to weed infestation, depending on the severity of infestation.

Table 15: Percent of respondents for weed control measures by geogs

Weed control measures	Geog						Total
	G/pphu	J/cling	U/ling	G/ney	S/soo	C/mari	
Hand weeding	70	66.7	100	100	92.3	100	88.2
Both hand weeding & herbicide	30	33.3	-	-	7.7	-	11.8

Diseases

Of the total respondents, 75% (Table 16) reported problems related to diseases in rice crop. Definite diagnosis of diseases and symptoms is beyond the scope of this study and it will require in-dept study of diseases at field level by a specialist in future to adequately tackle the problems of diseases.

Table 16: Percent of response for disease problems in rainfed rice crop

Disease problems	Geog						Total
	Gelephu	Jigme-choling	Umling	Ghumau-ney	Sibsoo	Chang-mari	
Yes	5.3	3.9	3.9	2.6	6.6	2.6	25.0
No	7.9	15.8	9.2	17.1	10.5	14.5	75.0
Total	13.2	19.7	13.2	9.7	17.1	17.1	100 n=76

However, through the interviews, some basic information was obtained with regards to disease problem in the survey area. Panicle sterility, wherein panicles turn whitish and fail to form grains, accounts for 46.7% of the total incidences. Yellowing and drying of whole plants in patches, which is common under drought condition in early stages of the crop, accounts for 20% of the total incidences. However, the cause for the above two problems are not ascertained whether it is due to pathogens or manifestation of drought stress. Incidences of node-blast, base rot and leaf spots are also reported in the system.

The practice of chemical spraying is practiced by as low as 17.6% of farmers. Traditional practice of draining out water from the field is practiced by some farmers to reduce crop damage during severe disease outbreak but effectiveness of the method is not known. It is estimated that the diseases accounts for 1-50% reduction in rice grain yield, depending upon the nature and severity of out-break.

Insect Pest

About 79% (Table 17) of the respondents reported insect pest problem in their rice field of which the major ones are shoot borer and case worms reporting 37% and 35% of the total incidences, respectively.

Table 17: Percent of respondent for problems of insect pest across geog

Response	Geog						Total
	G/phu	J/cling	U/ling	G/ney	S/soo	C/mari	
Yes	10.5	13.2	10.5	13.2	17.1	14.5	78.9
No	2.6	6.6	2.6	6.6	-	2.6	21.1
Total	13.2	19.7	13.2	19.7	17.1	17.1	100 n=76

Control measure is not practiced or known by as much as 48.2% of the total households. Insecticide spraying with the help of extension agents is done by as few as 28.6% of the sampled farmers and other measures, like flooding and controlled irrigation, is practiced by some farmers having assured and adequate irrigation. Insect pest is estimated to cause 22% of reduction in yield.

Vertebrate Pest

Vertebrate pest is the major problem in rice crop in the region. All the respondents expressed serious concern to the damage of standing crop by elephants (42%), monkeys (26%), wild boar and rodents. Approximately, damage due to vertebrate

is responsible for an average 47% reduction in production from the field. Under severe cases of attack, especially by elephants, 80-100% of the standing crop is reported to be damaged and the farmers are left with nothing to harvest. Guarding is the only control means employed, which often accounts for maximum labor and time spent by farmers in the rice production in the rainfed environment, which is often ineffective against animals like elephant, leading to complete destruction of the crop.

Constraints Due To Storage Pests

Drying of plants in the field is common practice through out the survey region. A slight shower after the harvest adversely affect the quality of grains and milling recovery and sometimes rainfall extended for weeks leads to complete loss of the harvest. Grains are usually stored in wooden boxes (54%), gunny bags (35.5%) and closely knitted bamboo or cane baskets (Table 18).

Table 18. Percent of respondents for type of storage containers used

Container type	Frequency	Percent
Gunny bags	27	35.5
Wooden boxes	41	53.9
Bamboo/cane baskets	8	10.5
Total	76	100.0

Grain-moth is major pest (55%) that damages the stored rice (Table 19), followed by weevil (31%). Rodents cause damage but to a limited amount. Storage pest is estimated to cause reduction 13% of total produce while storing.

Table 19: Percent of respondents for different storage pest incidences

Storage problems	Dzongkhag		
	Sarpang	Samtse	Total
Weevil	16.4	14.9	31.3
Grain moths	22.4	32.8	55.2
Rats	7.5	4.5	11.9
Others	1.5	-	1.5
Total	47.8	52.2	100 n=76

Labour use and mechanization

By virtue of rice cultivation being an intensive farming, shortage of labour is always a serious concern. Cent percent of respondents reported shortage of labour as a constraint for rice cultivation, wherein the family labour is not enough for rice cultivation. The household meet their labour requirement either by hiring external labour or by exchange of labour within the community. The rate of payment for labour ranged from Nu.50-100 per day, differing from village to village. The hire charge for a pair of bullock for a day ranged from Nu.150 to Nu. 180.

Overall, to cultivate an acre of land, approximately 97 men-days of labour are required and an addition of 60 men days for guarding the crop against vertebrate pest (Table 20). In a season, 20 pairs of bullock/day are required for cultivating an acre of rice crop under the rainfed lowland environment.

Table 20: Mean of labour and bullock requirement for different rice cultural operations

Operations	Labour (men-days/acre)	B.ullock (pair-day/acre)
Land preparation	22	12
Sowing	2	1
Nursery management	3	-
Transplanting	19	7
Irrigation management	13	-
Weeding	18	-
Crop guarding	60	-
Harvesting	12	-
Threshing & cleaning	9	-
Total	157	20

The level of farm mechanization is very minimal, i.e. 4% of the total households (Table 21). Exploring the possibilities of mechanization and equipping farmers with efficient labour saving devices will make rice cultivation attractive and save labour and time, which in turn will improve income generation of the household.

Table 21: Agriculture Machinery owned

Owning farm machines	Frequency	Percent
Yes	3	3.9
No	73	96.1
Total	76	100

Production status

The production of rainfed rice is far from being self-sufficient. The rice produced is often not adequate for consumption. Surplus production is reported in as low as 9.2% (Table 22) of the surveyed household, the rest reported shortage (46.1%) or just sufficient (44.7%) for consumption even when supplemented with other cereals like maize, millet and wheat.

Table 22: Percent of respondents for production status of rainfed rice by geogs

	Geog						Total
	G/phu	J/ling	U/ling	G/ney	S/soo	C/mari	
Shortage	2.6	9.2	6.6	14.5	6.6	6.6	46.1
Just enough	9.2	6.6	6.6	3.9	7.9	10.5	44.7
Surplus	1.3	3.9	-	1.3	2.6	-	9.2
Nos. of respondents	10	15	10	15	13	13	100 n=76

Farmers with insufficient production meet their requirement by purchasing rice from the nearest market or from neighboring farmers. Acute shortage of rice is reported during the month of July (transplanting time) - September (prior to new harvest of paddy), for a duration of 3 months.

CONCLUSION

The Wet Subtropical rice growing zone consists of 40% of total rice area in the country but contributes only 29% of the total production. At the household-level,

rice shortage is reported in 46% of the total household and estimated at 4 months. Despite much improvement in rice research and development the low contribution of WST to the total rice production indicates that it did not fare well. The households of mid-altitudes benefited the most from the research efforts in the past because most efforts were concentrated in generating technologies for the favourable irrigated conditions of mid altitude. The production system of rainfed rice was not understood in the past and hence no conscious effort could be made to improve production in this environment. Thus this study was conducted to throw light upon the nature of growing environment and gain a better insight to the production system of WST.

The WST largely represent rainfed lowland rice system with slight transition of irrigated system, wherever the source of irrigation is assured. Typically, the rice environment is constrained by assured source of irrigation and crops are often exposed to drought stress during critical stages. During the rainfall season, landslides and erosion are a serious concern to all farmers of the region, often damaging water conducting system and disrupting the continuity of discharge of water.

The production status of the rice in the given environment is far from sufficient where 45% of farmers reporting shortage and have to depend on other cereals and purchase rice from the market to sustain the household. To increase production of rice in the given environment will require multiple interventions from agricultural research, extension and policy support for agriculture development. However, the details and manners of necessary multiple interventions are beyond the scope of this study. Following suggestions specifically related to rice research and development under the rainfed environment are made on the basis of findings of the survey.

Primarily, lack of assured irrigation is the limiting factor in rainfed lowland rice area. Irregular and erratic rainfall causes a major damage to canals by landslides, wash-aways and erosions. Repairing and stabilizing the old traditional conducting channels with improved concrete materials, especially in case of perennial sources, will significantly reduce the problems of water deficiency. A thorough study and analysis is suggested to assess the need of allocating resources in the development of irrigation facilities in the rainfed eco-system.

Uncertain rainfall and lack of assured source of water often expose rice crop to drought stress, which especially during critical stages adversely affects the productivity. Long term knowledge on climatic condition of a locality will be essential in developing suitable varieties that will outperform existing varieties in a given environment. Hence, the proposed change in effort is the shift from broadly

adapted plant type to developing plants for target environment for sharper and precision increment in productivity through thorough on-farm testing of promising materials in as many locations as possible. Development of drought tolerant varieties with stable yield, across locations and seasons can also contribute to enhance production.

The overall mean yield of rice varieties in the survey region is low (680 kg/acre). The low productivity of rice in the region is due to low yield and low adoption of MVs. Despite significant yield advantage of MVs over local varieties (i.e. 153 kg/acre) and the rate of adoption of 44% of household, the extent of cultivation in terms of acreage within the household is very small. The low adoption rate of MVs is due to farmers' preference for varietal traits of locals such as good taste, stable yield and easy threshability. Developing suitable high yielding varieties through cross breeding but at the same time retaining the preferred traits of locals will substantially increase production. Besides, improving the yield of existing MVs, will also bring a quantum increase in production.

The low use of synthetic fertilizer and herbicides is also a factor behind low rice productivity. Unavailability or poor access to chemical fertilizers and herbicides is the main reason cited for its low use. Improvement of farmers' access to such inputs through better extension services could bring improvement in rice production. Similarly, developing appropriate technologies in nutrient, weed and pest and disease management seem desirable to improve the productivity. Hence, multiple interventions of specialists in soil and nutrient management and plant protection is necessary to clearly understand and develop appropriate technologies to address problems of soil, and biotic stresses (weed, pest and diseases).

Rice cultivation is labour intensive operation which is estimated to require 157 men-days/acre per season, including the labour requirement for guarding the crop against vertebrate pest. Topographically, the survey region offers a great opportunity for mechanization but the use of farm machineries is relatively very low (4%) compared to that of irrigated environment. Hence, there is a need to explore the possibilities of providing support in terms of labour saving devices and reduce the drudgery of rice farming.

Detailed and in-depth understanding of rainfed system with regards to parameters like rainfall patterns and subsoil hydrology in addition to the existing knowledge of surface irrigation is lacking. Integrated approach is necessary for characterizing the rainfed lowland agro-ecosystem both for use in technology extrapolations and recommendation domains and as a tool for diagnostics of technology generated.

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Existing Resources, Practices and Potentials of the Arecanut within the East-Central Region (Sarpang Dzongkhag)

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ABSTRACT

Arecanut (Areca catechu L) commonly known as betelnut is a tropical palm cultivated for its nuts. It is cultivated in the lower humid sub-tropical areas (below 600m) of Bhutan. A survey conducted in Sarpang Dzongkhag found that the crop was introduced by the farmers themselves about 70 years ago from neighbouring Assam, India. The crop agronomy and management practices are self acquired. There are 4 unknown varieties or types known by the shape of the fruits. Majority of the farmers raise their own planting material. Major pests and diseases are shoot rot or bud rot, fruit drop, ants, and stem borer or stem rot. Yield per hectare varied greatly. Some of the constraints are reported to be irrigation, pests and diseases and fruit drop.

KEYWORDS: Arecanut, resources, management practices, intercropping, pest, diseases

INTRODUCTION

Arecanut (*Areca catechu L*) or commonly known as betelnut is a tropical palm cultivated for its nuts. The plant is tall with slender erect, unarmed and solitary stems living for 60-100 years. The nuts or the hard dried endosperm of ripe and unripe seeds are chewed as a masticatory by about 400 million people around the world from Zanzibar to India and the Central Pacific. The nuts are chewed fresh or dried. The popular practice is to wrap small slices of the nut in a fresh leaf of betel-pepper (*Piper betle L*) which has been added with a dab of slaked lime. Other ingredients such as cardamom, tobacco, and clove may also be added to the betel quid. It is also commonly chewed in Bhutan and is customary in celebrations and ceremonies. Chewing is said to increase the production of saliva and gastric juices and thus aid digestion. The nut also has various medicinal uses: as a vermifuge for

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humans and animals, as a cure for diarrhoea, urinary disorders, edema and lumbago. It also has astringent and tonic properties. The nut is applied externally to ulcers, sores, swellings, and skin diseases. The husk, young shoots, buds, leaves and roots also have medicinal uses. Although the exact origin of *Areca catechu* is unknown, it most probably originated from Central Malaysia. The cultivation spread to the Indian sub-continent in pre-historic times (Vossen and Wessel 2000).

Today, the major arecanut growing countries are India, Sri Lanka, Bangladesh, Malaysia, Indonesia and the Philippines, with India leading the world production. In Bhutan arecanut could have been introduced a long time ago from India. It is grown in the sub-tropical southern districts of Sarpang, Samchi and Samdrup Jongkhar. In the lower humid sub-tropical areas (below 600m) of these Dzongkhags, arecanut cultivation is seen as one of the main cash crops providing high income with relatively low investment. Compared to other cash crops, arecanut is non-perishable and can be marketed in different forms (green, ripe and dried). The area under the crop has gradually increased over the last few years. In Sarpang Dzongkhag for example, the area has increased from 31 hectares in 1995(LUPP 1995) to over 170 hectares in 2001 (Nawang, personal communication). Arecanut is one of the main cash crops of Sarpang Dzongkhag after mandarin and cardamom. However, there have been limited inputs from the research and extension services largely because of limited knowledge on production management and varieties of this crop.

A survey was therefore conducted in Sarpang Dzongkhag in 2000 with the following objectives:

- Document existing resources, practices, constraints and potentials
- Identify areas for research and extension interventions

MATERIALS AND METHODS

A structured questionnaire was used for interviewing farmers and field observations made during the visits from September to November 2000. All the arecanut growing geogs of Sarpang Dzongkhag were covered viz: Hillay, Singye, Sarpangtar, Dekiling, Bhur, Gelephu, Umling, Chuzegang, Sershong and Kalikhola Dungkhag. A total of 137 farmers were interviewed who were selected based on their plantation size and experience in cultivation.

RESULTS AND DISCUSSION

Origin of Arecanut in the Dzongkhag

According to the growers of Sarpangtar and Dekiling geogs, arecanut was first introduced by a Lapchand family. Growers of the other villages could hardly trace back the time of introduction. However, the first planting materials were said to be brought from neighbouring Assam, India. Farmers' experience of arecanut cultivation ranged from over 3 to 70 years with a majority (48%) cultivating for more than 10 years.

Varieties

There are no known varieties. However there are about 4 types known by the shape of the fruits viz: Round (locally known as Jazi), Oblong (locally known as Lamchey), small oblong and small round. Round type with thinner husk is preferred because of its larger nut size with more whitish layer inside which is reported to be less intoxicating compared to nuts with more amount of reddish colored endosperm. Small Oblong is the least preferred nut type. Over 79% of the farmers grow the round type followed by Oblong (61%), Small oblong (18%), and Small round (7%).

Production Management Practices

Current management practices employed by arecanut growers are self acquired. The crop did not receive any technical and institutional support in the past. This is mainly because of the limited technical expertise within the Ministry of Agriculture.

Nursery

About 83% (114 respondents) of the farmers raise their own planting material. The crop is propagated through seeds. Seed nuts are selected from the middle clusters of the second bunch from healthy, high yielding plants. Healthy, clean nuts are selected in May-June. Land to be used for seed beds is ploughed 2-3 times. The nursery is either under the canopy of existing arecanut plantation or in the open field. Seed nuts are immediately sown after harvest or within a week after letting the husk rot. The former method is said to have faster germination. Seed beds are mulched with betel leaves or straw. One year old seedlings are transplanted to primary nursery at 30-45 cm spacing. Seedlings are again transplanted the following year with increased spacing. Sometimes nurseries are maintained under shade such as banana and sesbania. Farmers transplant the seedlings 2-4 times before permanent planting in the field with a majority (64%) transplanting about 3 times

(see table 1 also). Very few (12%) do it four times. Growers believe that more numbers of transplanting shortens plant height and hastens fruit bearing.

Site Selection and Establishment

Sites with deep soils and good drainage are preferred since shallow top soil and gravelly soils leads to water stress during the winter and early spring. Plantations are commonly found near the houses. Planting space used is inconsistent ranging from 1-2.7m plant to plant (PP) x 1-3m row to row (RR) (table 1), but this could be mainly because of intercropping practiced by a majority. Manure is applied at planting time (table 1); while in the later years manure input is mainly through tethering of cattle practiced by over 40% of the farmers. A few farmers plant bananas and sesbania prior to planting to provide shade to young plants. The number of bearing trees owned by the farmers ranged from 10-2000 representing plantation area between 0.02-1.6 hectares (table 1).

Table 1: Plantation characteristics

Parameter	Average	Range
Area (hectares)	0.3	0.02- 1.6
Bearing trees per farmer (Nos)	180	10-2000
Transplanting in the nursery before final planting in the field (Nos)	2.8	2-4
FYM application at planting (kg/plant)	5	2-20
Planting space (PP x RR in m)	1.8 PP x 1.9 RR	1-2.7 PP x 1-3.2m RR

Field Management

Management inputs are minimal especially the usage of chemicals for soil management and plant protection. Weeding is done more than once with a few farmers doing 5-6 times in a year. FYM is generally applied and many tether their cattle in the plantation after the palms are at least 3 years old. Very few (<5%) practice mulching and irrigation (28%) within the plantation. Those who irrigate do it 1-4 times during the dry winter months mainly by making channels. A majority (45%) of those who irrigate do it monthly.

Intercropping

Intercropping is practiced by about 55% of the farmers interviewed. The most popular intercrop used is banana. Maize and millet are planted with arecanut particularly during the early years of the plantation.

In later years these annuals are largely replaced by perennial crops such as banana, fodder etc (fig 1). Intercropping maximizes land use and output per unit area providing additional income and crops.

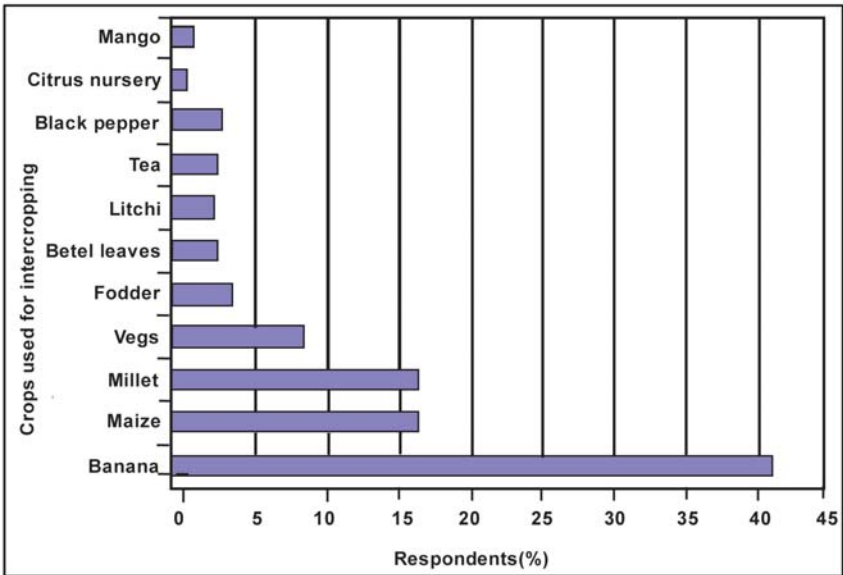


Figure 1: Crops used for intercropping (% of 75 respondents)

Pests and Diseases

Major pests and diseases are shoot rot or bud rot (*Phytophthora palmivora?*), (affecting growing shoot), fruit drop, ants, and stem borer or stem rot (fig 2). Shoot rot damage is serious and is reported to be causing economic losses with some farmers having lost 10-25% of their trees. This disease affects palms of all ages. It starts with yellowing of one or two young leaves surrounding the spindle. The spindle and the older leaves droop down followed by the rotting of tender leaf bases and soft tissues of the growing shoot. The leaf bases are forms a bulge, which is filled with foul smelling liquid. After the death of the central bud, the outer leaves and bunches remain intact for several months. The disease is mostly seen during the rainy season when the humidity is high. Farmers remove the palms at the bulging section.

Fruit drop is characterized by shedding of flowers and immature nuts occurring during April-May. A few farmers state that the incidence is higher during the dry period and in plantations with poor soils. This problem may be due to the fungus *Phytophthora arecae* or yellow leaf disease or due to water stress in spring. Chemical control measures are not practiced for any pests/disease problems.

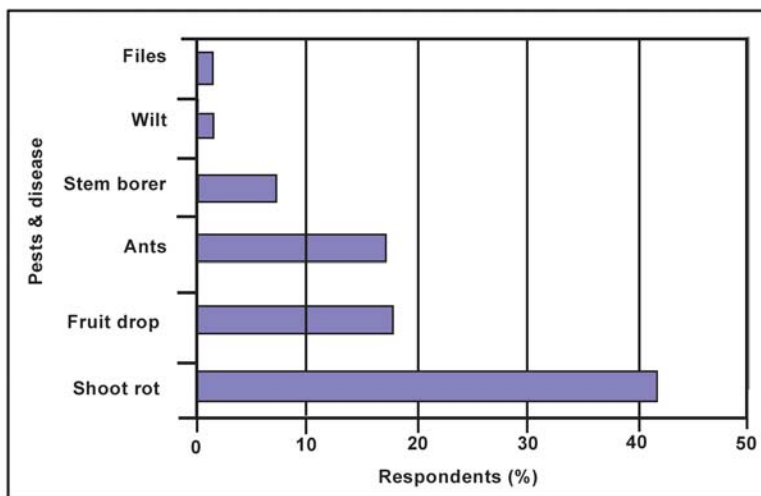


Figure 2: Major pests and diseases

Harvesting and Post-Harvest

Arecanut trees start bearing within 5-7 years of planting. The nuts are harvested either green or when ripe. Green nuts are harvested by late December and ripe ones from May-June. Harvesting is done manually with the help of a sickle tied to a long bamboo pole. A full bearing tree yields between 200-550 fruits per year. Based on the interview (47 farmers or 34% of the farmers interviewed provided some yield estimates), yield per hectare was estimated to be from 1200 to over 8600 kgs (table 2). The wide range could be mainly because of the age of the plantations, the number of trees per area and soil and management conditions.

There are three main forms of nuts sold in the market viz: kangcha, moza and supari. Green fruits locally called as “kangcha” are sold directly in the markets without curing. Ripe fruits are sometimes cured by burying them in soil pits lined with straw or bamboo mats or plastic.

The heap is made high above the ground and covered with soil, straw or plastics to prevent water into the pit. Fruits can be kept like this for up to eight months if

the pits are well prepared and buried. Cured nuts are known as “moza” and fetch higher price than “kangcha”. Nuts which are dried under shade or sun for 2-3 months are known as “supari”. Moza and supari forms are less intoxicating. Moza fetches the highest price. Both moza and kancha are equally popular in the market while supari is sold in very small quantities.

Table 2. Yield per hectare (% of 47 respondents)

Yield (kgs/hectare)	% respondents
1000-2500	15
2500-3700	9
3700-5000	21
5000-6200	15
6200-7400	4
7400-8600	6
>8600	30

Most arecanut growers sell their fruits while still on the trees to middlemen. Moza fetches around Nu 50 – 160 per pon (1 pon= 80 pieces) depending upon the season while kancha are sold for around Nu 30-70 per pon).

Constraints

Major constraints are reported to be irrigation, pests and diseases and fruit drop (fig 3). Irrigation constraints are in terms of facilities while wildlife refers to damages due to elephants.

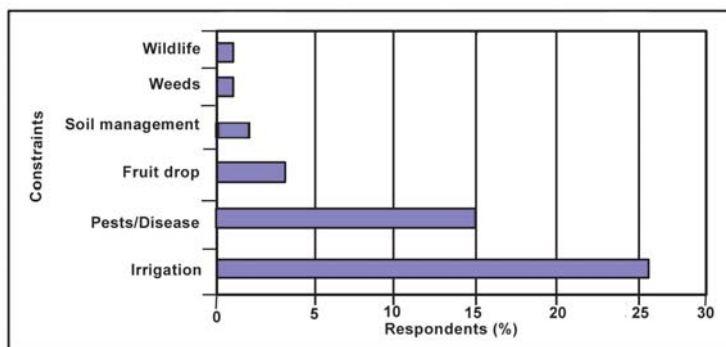


Figure 3: Major constraints reported

CONCLUSION

Specific areas requiring research inputs are on the following areas:

Varieties

- Since the existing varieties are unknown they need to be identified. Thereafter testing of other varieties should be done if required
- A simple selection programme should be initiated taking into account the preference of nut type including plant height, pest resistance etc.

Management

- Since some growers believe that the plant height can be decreased and fruiting advanced (fruiting 3-4 years after planting) by repeated transplanting in the nursery, studies on the effects of repeated transplanting may be conducted to identify the optimum number of transplanting required in the nursery. A simple survey on the existing plantations may also be done to confirm this.
- Farmers gave conflicting views on the effect of planting distance and use 1-3.2m spacing. To some extent this may be due to intercropping practiced by a majority of growers. However spacing effects should be documented by detailed observations in existing plantations.
- Some growers express that intercropping affects nut yields. Observations of plantations with intercropping may be initiated to find out the merits and demerits of intercropping.
- Soil fertility management is mainly through FYM and tethering of cattle. With the growing sizes of arecanut plantations, this has become impractical. Moreover, the potential yield attainable is not achieved because of minimal inputs. Therefore inorganic fertilizer recommendations may be developed.
- Irrigation is one of the major constraints reported. Flowering and fruit setting occur during the drier periods of the year. Moisture stress would greatly affect yield and quality. There is a need to document effects of moisture stress and benefits from irrigation.

Pest and Diseases

- Bud or shoot rot which is suspected to be due to *Phytophthora palmivora* and is becoming a serious disease and therefore based on the examination by the National Plant Protection Centre, control trials are being conducted.

- Fruit drop may be due to the disease koleroga caused by fungus *Phytophthora arecae* or yellow leaf disease (caused by Mycoplasm like organisms) or due to soil conditions such as water stress in spring (Dorji, 2000).

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Due acknowledgement and sincere thanks is extended to the Dzongkhag Agriculture staff of Sarpang for their valuable assistance in conducting the survey.

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Physico-Chemical Assessment of Water in Diverse Lentic Habitats of Bhutan

Shivaraj Bhattarai¹

ABSTRACT

Water samples collected from diverse habitats in Bhutan, mainly from the eastern Dzongkhags, were analysed for basic water qualities during the period from February 2000 to January 2002. Most of the sampled water bodies depicted their sub-tropical nature with their waters ranging from typically acidic to circum-neutral to slightly alkaline and with poor to moderate mineral contents. They are mostly well oxygenated and moderately hard to soft confirmed by methyl orange alkalinity, total hardness as well as by low calcium, magnesium and chloride contents, thereby also suggesting a need to supplement the water bodies with essential mineral nutrients in case of any future plans to harness them for biological productivity. Comparisons in water quality are also made with available reports from the Himalayan Region.

KEY WORDS: Bhutan, Himalayas, Freshwater, Water bodies, Water quality

INTRODUCTION

Freshwater is a valuable natural resource and the basis of existence of all life forms in our biosphere. Freshwater ecosystems of Bhutan cover only about 0.05% of the total land area while nearly 5.06% of land is under paddy cultivation (Anon, 1992). Aquatic habitats are scattered throughout the country in various ecological zones and these range from perennial rivers to seasonal rivulets, high altitude lakes and springs to lowland lakes, swamps, river floodplains and man-made reservoirs to village ponds and paddy fields. Among these lentic habitats, small and big wetlands in the form of swamps and bogs comprise an integral part of rural landscape even though many such habitats had been turned into paddy fields in the past. Besides providing aesthetic and wildlife values, these water bodies represent interesting ecotones that support wider diversity of aquatic communities but remain practically unexplored for harnessing their biogenic production potentials such as fishery.

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Except for preliminary observations on water quality by Arora (1990), Dhendup and Boyd (1994) and Sharma and Bhattarai (2005), there is lack of information on water quality of Bhutan. On the other hand, recently government's efforts are on to create the enabling environment to manage the water resources. Noteworthy initiative in this direction is the launching of Bhutan Water Partnership, an inter-ministerial organization, to coordinate and prepare national policies and legislations on water resources management (Gyeltshen, 2001). Of late, United Nations Environment Program (UNEP) along with remote-sensing experts from the International Centre for Integrated Mountain Development (ICIMOD) in Kathmandu, have conducted three years of research to assess the conditions of glaciers and glacial lakes in Bhutan some of which had shown catastrophic outbursts in the past. In view of the high importance placed on water resources and the lacunae in fundamental but vital information on water quality, this report bears great significance in bringing forth the basic physico-chemical features of Bhutanese waters which could form the baseline information for all future aquatic investigations in this country.

MATERIAL AND METHODS

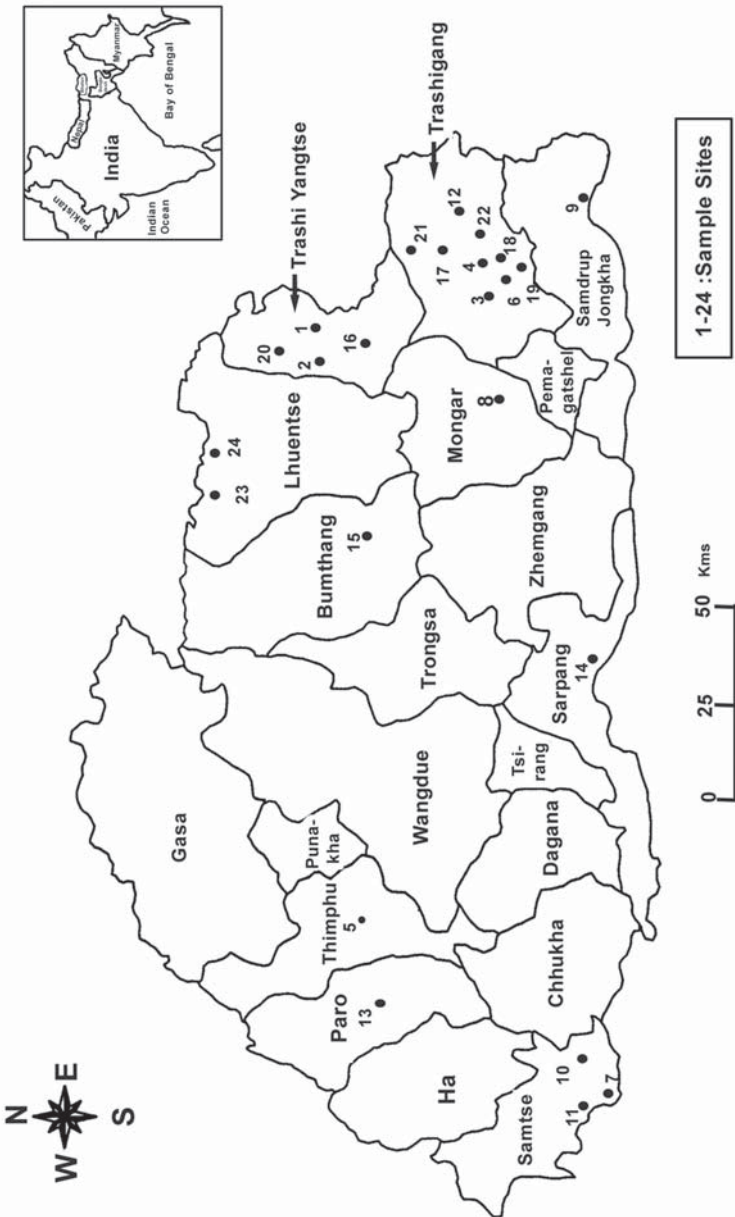
Water samples collected from diverse freshwater ecosystems (Table: 1) located at different climatic regimes of Bhutan (see map) were analyzed for basic abiotic factors. While temperature was recorded using a simple centigrade thermometer, pH and specific conductivity were measured with a standard pH and conductivity meter respectively. Dissolved Oxygen was estimated by modified Winkler's method and other chemical parameters such as free carbon dioxide, total alkalinity, total hardness, Ca, Mg and Cl were analyzed by following A.P.H.A. (1992) which involved standard titration methods.

RESULTS AND DISCUSSION

The observed abiotic parameters of these water bodies are presented in Table 2.

Temperature exerts the most profound direct or indirect influence on physico-chemical, biological, metabolic and physiological state of aquatic ecosystems. It also indirectly modifies the effect of other factors (Barbose, 1981) and influences the dynamics of living organisms (Chandler, 1942). It regulates growth, turnover rates and production of aquatic communities (Wetzel, 1983). In the presently surveyed habitats water temperature ranged widely between 1.1-29.5° C ($17.2 \pm 8^\circ\text{C}$) with the highest temperature recorded in a sub-tropical valley in eastern Bhutan (29°C) and minimum in a glacial lake (1.1°C) at an altitude of 4250 m AMSL both recorded in the morning of mid-May. Further eight of the studied

MAP SHOWING THE SAMPLING SITES DIFFERENT PARTS OF BHUTAN



ecosystems depicted average temperatures lower than 15°C, and these include: Site 24 (1.2°C) < Site 22 (4.0°C) < Site 13 (10.8°C) < Site 10 (10.9°C) < Site 20 (11.5°C) < Site 12 (12.5°C). Similarly Site 16 (29.5°C) > Site 9 (29.0°C) > Site 8 (26.8°C) > Site 11 (25.5°C) belonged to the category of ecosystems with an average water temperature above 25°C in summer, thereby depicting wide variations in the thermal continuum of waters in Bhutan.

Table 1: Salient Features of Study Sites 1-24

Site No.	Location/name	Altitude (m)	Other features/remarks
1	Nyagamtsho, Bumdeling	1930	In Bumdeling valley, Trashiyangtse, washed off in 2004 flood
2	Dungtsho, Bumdeling	1930	A peat bog in Bumdeling valley, near the school
3	Rongthong paddy field	1640	On the road side, approx. 18kms on Trashigang - S/Jongkhar highway; water-logged throughout year
4	Yonphula pond	3000	An ephemeral pond surrounded by pasture land, close to the helipad
5	Thimphu Sewage Ponds	2500	Highly eutrophic; sampled from the pond receiving final treatment
6	College Pond (Kanglung)	1820	A small man made pond in the campus
7	Mechetar Paddy field	250	At foothills in Samtse
8	Ngatshang Pond	1600	Ephemeral Pond, on the way to Monger
9	Fish Pond, Bhangtar	300	Mostly abandoned village fish ponds in S/Jongkhar
10	Sibichang, Dorokha	1150	A small perennial pond on the way to Dorokha from Samtse
11	Aalay, Mechetar	300	An ephemeral lake in foothills, Samtse
12	Danglingtsho Lake	3460	An alpine lake above Khaling town

Site No.	Location/name	Altitude (m)	Other features/remarks
13	Kichu resort ponds	2550	Recreational ponds in a resort in Paro
14	Gelephug Fishery Ponds	250	Series of warm water fish breeding pools
15	Bumthang- ponds	2600	Water loggings during rainy season near the town
16	Bumdeling Paddy field	1920	Paddyfield within Bumdeling valley
17	Chephu (Radhi)	2740	A shallow pond within an oak forest on the way to Merak from Radhi
18	Kanglung Paddy Field	1830	A low temperate paddy field
19	Pangthang Pond	1850	A small pond in Kanglung with thick growth of <i>Acorus calamus</i>
20	Yorbingsho	2570	A shallow pond within Rhododendron and oak mix forest above Bumdeling valley
21	Pond 'X' (near Site 17),	2740	A shallow pond with several fallen and decaying oak trees
22	Taktakpa	3150	A shallow pond within Rhododendron and oak mix forest above yonphula helipad
23	Tshona	4175	A glacial lake in Singye Dzong area near Bhutan-China border, partially melted in mid-May
24	Terdalatsho	4250	Similar to Site 23 about half kilometer from each other

TABLE 2: PHYSICO-CHEMICAL PARAMETERS OF AQUATIC ECOSYSTEMS (SITES 1-24)

Parameter? Study Sites?	1	2	3	4	5*	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Range	Mean \pm SD
Air Temperature (°C)	18.4	18.2	21.2	18.5	25.2	17.5	24.9	27.4	32.0	16.9	27.6	13.2	12.1	10.2	20.0	27.5	14.8	24.5	24.6	12.5	12.0	8.0	2.0	2.2	2.0 - 32.0	18.0 \pm 8.0
Water Temperature (°C)	17.2	16.4	19.7	18.7	23.3	15.4	24.6	26.8	29.0	10.9	25.5	12.5	10.8	15.4	19.3	29.5	17.5	23.2	23.1	11.5	15.5	4.0	1.1	1.2	1.1 - 29.5	17.2 \pm 8.0
pH	6.91	6.17	6.75	6.66	8.29	6.24	6.34	6.68	6.6	6.73	6.48	7.27	7.45	7.45	6.94	6.56	6.44	7.6	6.66	6.72	6.81	6.92	6.2	6.38	6.17 - 8.29	6.8 \pm 0.5
Sp. Conductivity (μ S/cm)	33	42	53	37	500	98	16	64	29	42	18.5	31	142	132	101	26	26	42	119	26	26	84	12	14	12 - 500	71.4 \pm 99.2
Dissolved Oxygen (mg/l)	5.4	3.4	7	6.47	2.4	3.84	6.4	6.8	11.2	12.8	12.2	6.4	9.2	6.56	4.8	3.5	13.2	2.3	5.2	5.2	5.6	7.2	16.0	11.0	2.3 - 16.0	7.3 \pm 3.7
Free Carbon dioxide (mg/l)	7.1	19.5	5.4	3.65	9.0	8.8	2.5	3.2	7.0	5.0	3.6	3.0	4.2	2.0	4.0	5.0	7.8	4.0	6.0	20.0	6.0	9.6	6.0	5.0	2.0 - 20.0	6.6 \pm 4.6
Total alkalinity (mg/l)	24.8	22.2	27.9	16.1	240.0	40.0	13.1	20.0	26.0	80.0	18.5	18.0	80.0	38.0	64.0	26.0	28.9	40.0	68.0	32.4	14.0	15.0	14.0	14.0	13.1 - 240.0	40.9 \pm 47.1
Total Hardness (mg/l)	16.4	18.3	22.0	11.0	76.0	36.0	8.8	24.0	24.0	28.0	9.6	7.0	11.0	58.0	40.0	26.0	18.0	24.0	62.0	12.0	8.6	12.0	10.0	16.0	7.0 - 76.0	24.1 \pm 18.3
Calcium Hardness (mg/l)	4.9	5.6	7.2	5.8	41.0	12.6	3.9	4.2	4.2	13.7	4.2	3.2	6.0	21.0	27.3	6.3	4.9	12.6	29.4	4.2	2.5	4.2	3.15	6.0	2.5 - 41.0	9.9 \pm 10.0
Magnesium (mg/l)	2.6	3.2	3.6	1.37	8.5	5.7	1.0	4.8	4.8	3.5	1.2	0.6	1.2	9.0	3.1	4.8	3.2	2.8	7.9	1.9	1.5	1.9	1.7	2.4	0.6 - 8.5	3.4 \pm 2.4
Chloride (mg/l)	4.2	4.7	4.6	2.5	42.0	11.0	2.5	8.0	5.0	5.0	3.0	2.1	3.5	9.0	11.0	6.0	4.5	11.0	14.0	4.4	4.2	6.3	4.0	4.5	2.1 - 42.0	7.4 \pm 8.0

* A highly eutrophic sewage stabilization pond

Hydrogen ion concentration (**pH**) of natural waters is governed to a large extent by the interaction between H^+ and OH^- ions formed due to dissociation of H_2CO_3 and hydrolysis of bicarbonates respectively (Wetzel, 1983). pH of raw water sources mostly lies within the range of 6.50-8.50 (Webber and Stumm, 1963). pH recorded at sampled localities in this study ranged from 6.17-8.29 (6.80 ± 0.50), thereby, depicting a slightly acidic to slightly alkaline nature of waters in Bhutan. More precisely, 13 out of 24 studied sites recorded pH less than 6.8 depicting acidic to slightly acidic nature of their biotopes. While Site 2 (peat bog) depicted the most acidic condition (pH 6.17) among the studied ecosystems, the other water bodies with pH less than 6.5 include Site 23 (pH 6.2) < Site 6 (pH 6.24) < Site 7 (pH 6.34) < Site 24 (pH 6.38) < Site 17 (pH 6.44) < Site 11 (6.48) stated in the order of their decreasing acidity. One of the water bodies viz. Site 12 (an alpine lake at 3460 m AMSL) shows pH of 7.27 depicting circum-neutral nature. Similarly, three of the ecosystems viz. Site 13 (a resort pond) and Site 14 (fishery pond) with pH 7.45 each and Site 18 (a paddy-field) with pH 7.6 fall within alkaline category. Further only one site i.e., Site 5 (sewage stabilization pond) was highly alkaline (pH 8.29). Following the classification by Venkateswarlu (1983), waters in eight of the sites fall within 'acidophilus' category (pH 5.5-6.7) and two in the alkaliphilus (pH 7.5-9.0). The remaining fourteen water bodies (58%) would fall under 'indifferent' (pH 6.5-7.5) or circum-neutral types. Recorded range and mean values broadly correspond with lentic ecosystems of Meghalaya (Sharma, 2001) but is marginally lower than earlier reports by Dhendup and Boyd (1994) in some ponds in Bhutan. Similarly, the presently recorded ranges and mean values are also lower than Begnas and Rupa lakes in Nepal (Swar and Fernando, 1979) as well as some wetlands in Kashmir in the far western Himalayas (Pandit, 1999) and report in three lakes in Kumaon Hill (Singh, *et al.*, 1982).

Specific conductivity or the ionic concentration of aquatic ecosystems is attributed to dissolved salts in water and is measured as specific conductance of electrolytes which, in turn, depicts total conductivity of various ionizable salts present. In this study the conductivity ranged between 12-500 $\mu S/cm$ (72.4 ± 99.2) exhibiting generally very low ionic concentrations of the sampled water bodies of Bhutan. Except in the sewage pond (500 $\mu S/cm$) and in a fertilized fish pond (132 $\mu S/cm$), the conductivity in other 22 natural water bodies ranged between 12-119 $\mu S/cm$ (49.2 ± 36.6 $\mu S/cm$) with the highest being in an ephemeral pond (Site 19) located at 1850 m AMSL. Further, Site 7 (16 $\mu S/cm$), Site 23 (12 $\mu S/cm$) and Site 24 (14 $\mu S/cm$) registered very low ionic concentrations (< 20 $\mu S/cm$). These values are generally below the normal ranges and indirectly indicate lack of adequate essential ions such as nitrate, phosphate, sodium, magnesium, calcium and iron for desired primary productivity. The present levels of ionic concentrations are also broadly concurrent with reports of Dhendup and Boyd (1994) except in one of the locations at Haa in western Bhutan (170 mS/cm). Similarly, the present values are broadly identical to water bodies of Meghalaya (Sharma, 2001) but are slightly higher than the reports of

Swar and Fernando (1979). However, specific conductivity values recorded are considerably lower than reports of some wetlands of Kashmir (Pandit, 1999) and also of Anchar Lake in that state (Sarwar, 1999).

Dissolved oxygen is an important indicator of trophic status of aquatic environs and is the basis for distribution, behaviour and growth of aquatic organisms (Wetzel, 1983). Dissolved oxygen in the studied ecosystems ranged between 2.3-16.0 mg/l (7.3 ± 3.7). Of these, ten sites exhibited well oxygenated waters (6.6-16.0 mg/l) while four water bodies depicted dissolved oxygen < 4.0 mg/l viz. Site 18 (2.3 mg/l) $<$ Site 5 (2.4 mg/l) $<$ Site 16 (3.5 mg/l) $<$ Site 6 (3.8 mg/l), the last two sites being a paddy-field at 1920 m AMSL and a small man made pond at 1820 m AMSL respectively in east Bhutan.

In addition, poor oxygenation was also recorded in eutrophic waters of sewage stabilization pond (2.4 mg/l) owing to high level of organic matter caused by decomposing algal bloom (Horne and Goldman, 1994). However, higher dissolved oxygen in two glacial lakes (16.0 mg/l and 11.0 mg/l respectively) could be due to greater diffusion of oxygen at low temperature and also apparently due to low community respiration. In general higher values were recorded in water bodies from lower altitudes including Site 11 (12.2 mg/l) $>$ Site 10 (12.0 mg/l) $>$ Site 9 (11.2 mg/l), apparently owing to higher partial pressure (Wetzel, 1983). Even though ranges in the present study vary more widely, mean dissolved oxygen values are within the normal ranges in the region and are identical to the reports of Sarwar (1999), Pandit (1999) and Sharma (2001) from the similar ecosystems in the nearby Himalayas.

Free **Carbon dioxide** contributes to the fitness of natural waters (Kaushik and Saksena, 1999) because it serves as a buffer and exists in equilibrium with bicarbonate and carbonate ions (Wetzel, 1983). The surface waters normally contain 10 mg/l of free CO₂, which is constantly utilized by the primary producers for autotrophic activities. Free CO₂ in the sampled water bodies ranged widely between 2.0-20.0 mg/l (6.6 ± 4.6 mg/l) with maximum values observed in a shallow pond (Site 20) at 3150 m ASL in eastern Bhutan. Minimum levels of free CO₂ were recorded in a fishpond at the foothills (Site 14) indicating its higher uptake by the primary producers.

Total alkalinity in the present investigations was exclusively attributed to methyl orange alkalinity, which, in turn, was contributed by bicarbonate ions. A normal range of total alkalinity is 20-200 mg/l in freshwaters and less than 10 mg/l indicate poorly buffered water. It exhibited wide variations i.e., between 13.1-240.0 mg/l (40.9 ± 47.0 mg/l) with highest at Site 5 (sewage stabilization pond) and lowest at Site 7 (a paddy-field in foothills). Among the other water bodies, four sites exhibited 'moderately hard' waters with total alkalinity of more than 50.0 mg/l (Wetzel, 1983 and Payne, 1986) viz. Site 10 (80.0 mg/l) = Site 13 (80.0 mg/l) $>$ Site 19 (68.0 mg/l) $>$ Site 15 (64.0 mg/l). These vary from a river-fed recreational pond (Site 13) to weedy

and shallow ponds (Sites 10, 15 and 19) to an occasionally limed fishpond (Site 14). These water bodies are less susceptible to pH changes and exhibit buffering properties. The carbonates and bicarbonates ions in these water bodies, which cause alkalinity, can also remove toxic metals like lead, arsenic and cadmium. On the other hand, seven water bodies depicted “very soft” characteristic with total alkalinity of less than 20 mg/l and they are Site 7 (13.1 mg/l) < Site 21 (14.0 mg/l) = Site 23 = Site 24 < Site 22 (15.0 mg/l) < Site 4 (16.1 mg/l) < Site 12 (18.0 mg/l) < Site 11 (18.5 mg/l) in the stated order of their decreasing alkalinity. Therefore, 70% of the sampled biotopes represented broadly ‘soft water’ characteristic (21.7 ± 7.2 mg/l) of lentic waters in Bhutan. The recorded values concurred with the earlier reports from Bhutan by Dhendup and Boyd (1994). Similarly, moderate alkalinity in six of the sites is considerably higher than waters from Meghalaya (Sharma, 2001) as well as from a lake in Sikkim (Jain *et al.*, 1999). However, range and mean alkalinity at 17 other sites correspond with cited reports. On the other hand, the present mean values are considerably lower than reports from further west viz. Kumaon and Kashmir (Singh, *et al.*, 1982; Pandit, 1999 and Sarwar, 1999).

Total hardness is mainly attributed to calcium and magnesium along with other cations such as potassium and sodium in combination with anions like bicarbonate and carbonate (temporary hardness) and with sulphate and chloride (permanent hardness). It varies greatly due to differences in geology. Total hardness in the sampled waters in Bhutan ranged between 7.0-76.0 mg/l (24.1 ± 18.3 mg/l). It depicted a ‘very soft’ nature of Site 12 (7.0 mg/l) > Site 7 (8.8 mg/l) > Site 11 (9.6 mg/l) > Site 23 (10.0 mg/l) > Site 4 = Site 13 (11.0 mg/l) > Site 20 = Site 22 (12.0 mg/l), representing diverse ecosystems located at different altitudes. On the contrary, moderately ‘hard-water’ at Site 5 (76.0 mg/l) > Site 19 (62.0 mg/l) > Site 14 (58.0 mg/l), in turn, representing the sewage stabilisation pond, a weedy and a marshy pond and a fishpond respectively, were recorded. All other 13 sampled biotopes fall under the category of ‘soft-waters’ as per the classification *vide* Payne (1986). The present finding broadly corresponded with the earlier reports of Dhendup and Boyd (1994). However the results are considerably lower than the reports of Quadri and Yousuf (1988), Sarwar (1999) and Pandit (1999) from western Himalayas, while the recorded values are largely identical to the ‘soft waters’ of Meghalaya state of Eastern Himalayas (Sharma, 2001).

Calcium content ranged between 2.5-41.0 mg/l (9.9 ± 10.0 mg/l) at all the sites with maximum concentration in sewage stabilization pond. However, in rest of the sampled water bodies, it ranged between 2.5-29.4 mg/l (7.4 ± 6.1 mg/l). While Site 19 (29.4 mg/l) > Site 15 (27.3 mg/l), represented relatively ‘calcium rich’ condition, Site 14 (21.0 mg/l) > Site 10 (13.7 mg/l) > Site 18 = Site 6 (12.6 mg/l) are waters with ‘medium’ calcium content comprising a limed fish pond (Site 14) to small ponds (Sites 6 and 10) and a paddy-field (Site 18); and the remaining 17 sites (70% of the sampled water bodies) affirmed ‘calcium poor’ conditions. Recorded calcium content

concluded with the reports of Dhendup and Boyd (1994). But it was significantly lower than the reports by Pandit (1999) and Sarwar (1999). While the present result is also lower than in Nainital Lake (Singh *et al.*, 1982), it concurred with the findings in Naukuchiatal Lake communicated in the above report. In addition, the presently recorded values are also identical to waters of Meghalaya (Sharma, 2001).

Magnesium is an important component of chlorophyll, a co-factor in enzymatic transformations (Wetzel, 1983) and is also a factor that contributes to total hardness of water. It ranged between 0.6-8.5 mg/l (3.4 ± 2.4 mg/l) exhibiting its low concentrations at all the sampled sites in Bhutan. While the present mean value of magnesium was only slightly lower than the reports of Sarwar (1999), it is significantly lower than the reports of Pandit (1999) but broadly corresponded with reports of Dhendup and Boyd (1994) and Sharma (2001).

Chloride is formed generally from dissolution of salt deposits of sodium, potassium and calcium and is usually found in low concentration in natural waters (Wetzel, 1983). However, influx from domestic sewage could sufficiently raise its content, thereby, indicating organic pollution in water bodies. In the present study it ranged widely between 2.1-42.0 mg/l (7.4 ± 8.0 mg/l) with highest chloride concentration registered at Site 5 (sewage stabilisation pond) as expected therefore indicated presence of organic pollutants (Wetzel, 1983). In all other water bodies the recorded values correspond with the reports of Jain, *et al.* (1999) and Sharma (2001) but marginally higher than the earlier reports from Bhutan by Dhendup and Boyd (1994). However, the chloride content in the present study is still slightly lower than the report of Pandit (1999) and substantially lower than the report of Sarwar (1999) from Kashmir areas.

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Current Status of the Odonata of Bhutan: A Checklist with Four New Records

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ABSTRACT

Specimens of dragonflies were collected from Trashiyangtse and Pemagatshel districts of eastern Bhutan during the months of July and September 2003. One specimen of Neurothemis fulvia was collected on 5th September 2004 Samdrup Jongkhar district. Altogether 61 specimens of Odonata belonging to 16 species and subspecies under 13 genera and four families were listed during the present study, which revealed four new records of odonates for Bhutan viz., Orthetrum s. sabina, Acisoma p. panorpoides, Brachythemis contaminata and Neurothemis fulvia. An up-to-date checklist of 31 species and subspecies of odonates known till date from Bhutan had also been made. However, since the collection period was too short and didn't spread over the whole year, the above list of odonata from the concerned localities remained incomplete. The survey did not cover the southern, western and central districts of Bhutan and thus does not represent a complete checklist of Odonates of Bhutan. An extensive Odonatological survey needs to be carried out to explore the rich diversity of these elegant insects and come up with a representative checklist of Odonates for Bhutan.

KEY WORDS: Bhutan, checklist, dragonfly, new record, Odonata, Pemagatshel, Samdrup Jongkhar, Tashiyangtse

INTRODUCTION

The insect order Odonata is divided into three suborders - the more delicate weakly flying damselflies (Zygoptera), the more robust dragonflies (Anisoptera) and a relict group of primitive dragonflies (Anisozygoptera). However, the odonatologists of the recent world commonly use the term "dragonfly" for the members of all the three suborders. According to Silsby, 2001, eight super families, 29 families and some 58 sub-families of dragonflies for approximately 600 genera and 6000 named species have so far been described all over the world.

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Dragonflies are predaceous, hemimetabolous and amphibiotic insects, which inhabits all kinds of freshwater habitats either permanent or temporary. Odonata experiences two totally different life styles. In almost all cases, the egg and larval stages are aquatic where as the adults are terrestrial (Silsby, 2001). The prey of the adults consists mostly of the harmful insects of crops, orchards and forests and thus has a regulatory impact on the agro-forestry. Their aquatic larvae constitute a natural biological control over mosquito larvae and thus help to control several epidemic diseases like malaria, dengue, filaria etc. (Mitra, 2002).

Being situated on the southern slopes of the Eastern Himalayas, the Kingdom of Bhutan is landlocked between China in the north and India to the east, south and west. Although quite a lot of work had already been done on the odonates of India and China, Bhutan is significantly little explored as far as the odonata diversity is concerned. Lieftinck (1977) reported only six species of odonates from Bhutan viz., *Caliphaea confusa*, *Megalestes major*, *Lestes (Indolestes) cyaneus*, *Calicnemia mortoni*, *Davidius baronii* and *Cephalaeschna triadica* and those were collected by the members of the “Zoologische Expedition des Naturhistorischen Museums Basel in das Konigreich Bhutan” in 1972. Tsuda (1991), in his distributional list of World Odonata, had enlisted only nine species from Bhutan that had added *Lestes concinnus*, *Aeshna p. petalura* and *Anax nigrofasciatus nigrolineatus* to Lieftinck’s (1977) list. Unfortunately, it was a mere checklist without any locality data or other information. Mitra (2002) had recorded 23 species and subspecies of odonates belonging to 18 genera under 10 families from Trashigang district in Eastern Bhutan that had added 18 new records to the existing list of odonata of Bhutan. During the present study 13 species and subspecies of odonata belonging to 11 genera fewer than four families were collected from the Trashiyangtse district; four species belonging to three genera under a single family were collected from Pemagatshel district and a single specimen of *Neurothemis fulvia* was collected from Samdrupjongkhar district by one of my students. All of these Odonates were maiden records from the localities concerned but four among these were new records for Bhutan as a whole and with this the checklist of Odonates for Bhutan had been extended up to 31 species and subspecies.

MATERIALS AND METHODS

Most of the samples were collected during a period of four days survey carried out in Tashiyangtse district of eastern Bhutan in July 2003. A few specimens were collected in September 2003 during a five days field visit to Pemagatshel district. The following localities were surveyed in the two districts of Tashiyangtse and Pemagatshel.

Tashiyangtse District:

Loc. 1: Tashiyangtse proper was surveyed on 19 July 2003. Collections were made from two small streams at an altitude of 1750m and the surrounding paddy fields.

Loc. 2: Bumdeling valley at an altitude of 2000m was surveyed on 20 July 2003. Collections were made from two small marshy ponds, few slow-running marshy streams and the agricultural fields surrounding the river Drangmechhu.

Loc. 3: Chorten kora was surveyed on 21 July 2003. Collections were made from a small pond (altitude: 1745m) situated half km away from the proper Trashiyangtse.

Pemagatsel District:

Only four species of Odonates were collected while going on foot through the hilly terrains from the following localities on respective dates.

Loc. 4: Nangkhor (1300m): 10 September 2003.

Loc. 5: Khar (1200m): 12 September 2003.

Loc. 6: Pemagatsel proper (1800m): 13 September 2003.

A total of 60 Odonata specimens were collected from the above localities using an insect net of 30 cm diameter. A single libellulid had been sent to me by one of my student of the district Samdrup Jongkhar (Loc. 7) that had been collected on 5 September 2004. Collections were made from all the different type of habitats like agricultural fields, weedy ponds, fast flowing streams, slow running marshy streams, riverbanks etc. Identification of the specimens was facilitated with the help of identification key provided by Fraser (1933, '34, '36) and the description given by Lieftinck (1977) in his foremost work on Bhutan odonates. Specimens had been persevered accordingly for their further submission to the museum maintained by the Life Science Departments of Sherubtse College, Kanglung, Bhutan.

RESULTS

A total of 16 species and subspecies of odonates spreading to five zygopterans and 11 anisopterans and belonging to 13 genera under four families that had been collected during the present study are listed below. The list also includes their locality data as well as the number of individual males and females collected.

1. *Ceriagrion fallax cerinomelas* Liefstinck, 1927 – Loc. 1: 3♂, 2♀; Loc. 2: 1♂.
2. *Ischnura a. aurora* (Brauer, 1865) – Loc. 2: 1♂.
3. *I. forcipata* Morton, 1907 – Loc. 1: 1♂; Loc. 2: 2♂, 1♀.
4. *Calicnemis eximia* (Selys, 1863) – Loc. 1: 2♂, 3♀; Loc. 2: 1♂, 1♀.
5. *Indolestes cyaneus* (Selys, 1862) – Loc. 2: 1♂.
6. *Orthetrum t. triangulare* (Selys, 1878) – Loc. 1: 2♂, 3♀; Loc. 6: 1♂, 1♀.
7. **O. s. sabina* (Drury, 1770) – Loc. 4: 2♀.
8. *O. taeniolatum* (Schneider, 1845) – Loc. 1: 1♂, 2♀; Loc. 3: 1♂, 1♀.
9. **Acisoma p. panorpoides* Rambur, 1842 – Loc. 3: 2♂, 1♀.
10. **Brachythemis contaminata* (Fabricius, 1793) – Loc. 4: 1♂.
11. *Crocothemis s. servilia* (Drury, 1770) – Loc. 1: 1♂, 1♀; Loc. 2: 3♂, 1♀.
12. *Diplacodes trivialis* (Rambur, 1842) – Loc. 1: 2♂; Loc. 3: 1♂, 1♀.
13. **Neurothemis fulvia* (Drury, 1773) – Loc. 7: 1♂.
14. *Sympetrum commixtum* (Selys, 1884) – Loc. 2: 3♂, 2♀.
15. *Palpopleura s. sexmaculata* (Fabricius, 1787) – Loc. 1: 1♂, 1♀; Loc. 2: 1♂, 2♀; Loc. 4: 1♂.
16. *Pantala flavescens* (Fabricius, 1798) – Loc. 2: 2♂ (Lot many were seen on wing).

(* represents the new records)

Compiling the results obtained from the present study together with the lists of Liefstinck (1977), Tsuda (1991), Mitra (2002), an updated checklist of dragonflies for Bhutan has been prepared.

Checklist of Dragonflies for Bhutan Known till Date

- Order – Odonata
 Suborder – Zygoptera
 Superfamily – Coenagrionoidea (Closed wings)
 Family – Coenagrionidae (Pond damselflies)
 Subfamily – Pseudagrioninae
 Genus – *Ceriagrion* Selys, 1876
 1. *Ceriagrion fallax cerinomelas* Liefstinck, 1927
- Subfamily – Ischnurinae
 Genus – *Ischnura* Charpentier, 1840
 2. *Ischnura forcipata* Morton, 1907
 3. *I. a. aurora* (Brauer, 1865)
- Family – Platycnemididae (Brook damselflies)
 Subfamily – Calicnemidinae
 Genus – *Calicnemis* Strand, 1926

- 4. *Calicnemia eximia* (Selys, 1863)
- 5. *C. mortoni* (Laidlaw, 1917)
- Superfamily – Lestoidea (Open wings)
- Family – Lestidae (Reedlings)
- Subfamily – Sympecmatinae
- Genus – *Indolestes* Fraser, 1922
- 6. *Indolestes cyaneus* (Selys, 1862)
- Subfamily – Lestinae
- Genus – *Lestes* Leach, 1815
- 7. *Lestes concinnus* Hagen in Selys, 1862
- Family – Synlestidae (Sylphs)
- Subfamily – Megalestinae
- Genus – *Megalestes* Selys, 1862
- 8. *Megalestes major* Selys, 1862
- Superfamily – Calopterygoidea (Broad wings)
- Family – Calopterygidae (Demoiselles)
- Subfamily – Caliphaeinae
- Genus – *Caliphaea* Selys, 1859
- 9. *Caliphaea confusa* Hagen in Selys, 1859
- Family – Euphaeidae (Gossamer wings)
- Genus – *Anisopleura* Selys, 1853
- 10. *Anisopleura comes* Hagen, 1880
- Suborder – Anisoptera
- Superfamily – Aeshnoidea (Angle wings)
- Family – Gomphidae (Clubtails)
- Subfamily – Onychogomphinae
- Genus – *Onychogomphus* Selys, 1854
- 11. *Onychogomphus biforceps* (Selys, 1878)
- Subfamily – Gomphinae
- Genus – *Davidius* Selys, 1878
- 12. *Davidius baronii* Lieftinck, 1977
- Family – Aeshnidae (Hawkers)
- Subfamily – Aeshninae
- Genus – *Anax* Leach, 1815
- 13. *Anax nigrofasciatus nigrolineatus* Fraser, 1935
- Genus – *Aeshna* Fabricius, 1775
- 14. *Aeshna p. petalura* Martin, 1906
- Subfamily – Brachytroninae
- Genus – *Cephalaeschna* Selys, 1883

15. *Cephalaeschna triadica* Lieftinck, 1977
- Superfamily – Libelluloidea (Dippers)
 Family – Corduliidae (Emeralds)
 Subfamily – Macromiinae
 Genus – *Macromia* Rambur, 1842
16. *Macromia moorei* Selys, 1874
- Family – Libellulidae (Perchers)
 Subfamily – Libellulinae
 Genus – *Orthetrum* Newman, 1833
17. *Orthetrum t. triangulare* (Selys, 1878)
 18. *O. s. sabina* (Drury, 1770)
 19. *O. taeniolatum* (Schneider, 1845)
 20. *O. pruinatum neglectum* (Rambur, 1842)
 21. *O. luzonicum* (Brauer, 1868)
- Subfamily – Sympetrinae
 Genus – *Acisoma* Rambur, 1842
22. *Acisoma p. panorpoides* Rambur, 1842
- Genus – *Brachythemis* Brauer, 1868
23. *Brachythemis contaminata* (Fabricius, 1793)
- Genus – *Crocothemis* Brauer, 1868
24. *Crocothemis s. servilia* (Drury, 1770)
- Genus – *Diplacodes* Kirby, 1889
25. *Diplacodes trivialis* (Rambur, 1842)
- Genus – *Neurothemis* Brauer, 1867
26. *Neurothemis fulvia* (Drury, 1773)
- Genus – *Sympetrum* Newman, 1833
27. *Sympetrum commixtum* (Selys, 1884)
- Subfamily – Trithemistinae
 Genus – *Trithemis* Brauer, 1868
28. *Trithemis aurora* (Burmeister, 1839)
 29. *T. festiva* (Rambur, 1842)
- Subfamily – Palpopleurinae
 Genus – *Palpopleura* Rambur, 1842
30. *Palpopleura s. sexmaculata* (Fabricius, 1787)
- Subfamily – Trameinae
 Genus – *Pantala* Hagen, 1861
31. *Pantala flavescens* (Fabricius, 1798)

Note: All the scientific and common names of the different taxa are as per Fraser (1933, 34, 36), Prasad and Varshney (1995) & Silsby (2001).

DISCUSSION

Earlier 23 species of Odonates have been recorded from the Trashigang district (Mitra 2002) of eastern Bhutan. During the present study four species and subspecies of odonata consisting of four anisopterans viz., *Orthetrum s. sabina*, *Acisoma p. panorpoides*, *Brachythemis contaminata* and *Neurothemis fulvia*, have been recorded for the first time from Bhutan. However, due to the short study period and the lack of seasonal coverage, the present list of Odonates from the concerned localities is still incomplete. Moreover, the present study only included certain parts of three eastern districts and places in western, southern and central districts have not been Odonatologically explored. The number of odonata species known from Bhutan (31) till date is very little in respect to Nepal (172), Bangladesh (114), Srilanka (111) and India (499) (Prasad and Varshney 1995). Being one of the global hotspots of biodiversity and remaining sandwiched between India and China, Bhutan needs an extensive survey to explore its rich Odonate diversity, which will certainly contribute to the list of the world Odonata. Until this is done, the list of Odonates for Bhutan will remain incomplete.

ACKNOWLEDGEMENTS

I am grateful to Mr. Dorji Tshering, the then Principal, Sherubtse College, Kanglung, Bhutan for administrative and logistic support. I would like to thank all the concerned RGOB officials for their permission to survey. I am also grateful to my students, Mr. Bharat Humangi, Ms. Lhaden & Ms. Tshering Yangzom of B.Sc. III, who had accompanied & helped me a lot during the trip to the district Trashiyangtse. I would also like to thank Mr. Sangay Thinley (ex-student) for collecting the single specimen of *Neurothemis fulvia* from the SamdrupJongkhar district.

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Demonstration of Integrated Rice-Fish Culture under Bajo Research Conditions

Dawa L Sherpa¹

ABSTRACT

Rice and fish go together as food in many parts of the world and so is in Bhutan. The synchronous system of fish cum rice culture is adopted for productive utilisation of land both for crop and fish production to supplement the income to the farmers. Pursuant to this view, two years experiment was carried out at Bajo, Wangdue to validate the information generated by fishery researchers afresh. The plots were renovated by excavating canals, pools or trenches to retain water. This would provide shelter to fish and stored water could be used for the irrigating crops. 'I' shaped trenches were dug with depth of 80cm and width of 60 cm on top on both sides of the plots.

*The two years experiment indicated that the growth rate of Common carp (*Cyprinus carpio*) was found to be much higher compared to Grass carp (*Ctenopharyngodon idella*). The first year results revealed that Common carp weight ranged between 170-410 gm compared to 30-80 gm only from that of Grass carp within a period of 90 days. In total, Common carp yielded 11.2 kg and 3.5 kg Grass carp. During the second year of experiment, the yearlings were reared instead of fingerlings. About 200 Common Carp and Grass Carp were released in the field. The fish were harvested at 110 days of growth period in the rice field. On the day of harvest 190 out of 200 Common Carp were counted which yielded 15 kg in total. Out of a total of 200 Grass Carp yearlings released only 60 were found available on the day of harvest. The total yield from Grass Carp was only 3 kg. Further it was noted that their growth rate was optimal and overall survivability was found to be quite good amongst the species. Some degree of predation was noticed by aquatic birds which was unavoidable. The fingerlings might have also escaped through the holes of the bunds made by insects and rodents especially during night time that ultimately contributed to over loss. However during the entire trial period no major mortality and diseases occurrences were observed. To validate existing information and draw suitable future recommendation, more research needs to be conducted on-farm.*

KEYWORDS: Rice fish culture, integrated, grass carp, common carp, feeding, yield, comparative

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INTRODUCTION

Rice- fish culture consists of stocking of fish seed in rice field where rice is the principal crop and fish culture has to adapt to the conditions and requirement of the rice crop. The main advantages of this system are reported to be:

- Economic utilisation of land both for the production of rice and fish
- Diversified cultivation; the production in one crop can be compared with the production of other
- Animal protein, an important component of human diet, can be acquired by rice-fish culture system
- Rice production is increased by 10-15% (Pradhan, 1979) due to increased organic fertilization and reduced insect and pest pressure (Schuster et al 1955)
- Helps in eliminating some of the major weed that pose threat to rice farming
- Less labour and production costs are incurred in this system as extra labour cost is compensated by fish feeding in weed which otherwise require manual weeding.
- It is a beneficial opportunity to obtain better income for the farmers.

Some of the fish species commonly raised in rice system are Grass Carp (*Ctenopharyngodon idella*) and Common Carp (*Cyprinus carpio*). These fishes have the habitat of feeding extensively in phytoplankton, zooplankton and minute algae that are commonly available to them in the rice field. These fishes grow well in the rice-fish culture system. Research conducted by National Warm Water Fish Culture Centre, Geylegphu compared the yield differences and economics of growing rice as mono crop and with rice-fish culture system. Some of their results are quite interesting although research in other locations have not been conducted till date. It is therefore felt imperative to carry out a similar kind of study in Wangdue to share our findings on this integrated approach and their comparative advantages with relevant stakeholders and the farmers.

OBJECTIVES

- To demonstrate integrated rice-fish production methods to the rice-based farmers, to provide options for the farmers as an additional source of income and family nutrition through this integrated farming approach
- To understand the influence on rice yield as a mono crop and as rice-fish system

MATERIALS AND METHODS

During the first year, about 800 Grass Carp and Common Carp fingerlings were procured from Geylegphu. In the second year, 400 numbers of Common and Grass Carp yearlings were introduced in the same plots. The rice field having areas of 600m² were readied after consultation with the field crop colleagues where there was perennial source of running water. One large terrace was used for this experiment. The other material required was the wire mesh net to prevent the mixing of fingerlings from another compartment. Supplement feed consisting of maize grit, rice bran and oil cake were fed to fish. In addition to this, fresh manure application from time to time was done to maintain plankton's population and diversity.

Methods

Field Trial Setting

A 600m² rice terrace was divided into two compartments of equal size for Common Carp and Grass Carp. The plots were netted with wire mesh to prevent mixing of fish from one compartment to other. In the first year, about 400 numbers each of Grass Carp and common Carp fingerlings were introduced. During the second year, about 200 Common and Grass Carp yearlings were released. Both the plots were transplanted rice of same variety. A minimum area of 600m² was maintained in both plots to allow fish growth. The fingerlings were stocked at the rate of 0.2 per square metre for Grass Carp and 0.1 for Common Carp as minor stocking in experimental field of circular trench when the fingerlings are of 10-12cm length and 9-12 gm weight. For the rectangular trench, the stocking rate is 0.6 per meter square and as the fingerlings grew the size was gradually increased to 2.5 m² / fish. In the inlet and outlet, the wire mesh was netted to prevent mixing of fishes and to regulate water level and maintain water temperature. A trench of 80cm wide and 80cm deep was made throughout the plot from two sides to maintain regular water flow and also to ease fish harvest. A minimum of 6-10cm deep water levels was maintained in the rice field at all time. The water temperature was maintained between 25-30°C. The rice was transplanted at a distance of 15-20 cm plant to plant and a row distance of 20cm. Data on the growth rate; disease incidences, , supplement feeding and other production variables were collected. The fish was reared till the time of the rice maturity and harvested a week before rice harvest. The rice and fish yield from treatment plots and rice production from control plots were assessed and quantified. Direct cost benefit analyses were done to compare the outcome of the trial.

Agronomic Practices of Rice- Fish Culture

For rice production, basal dose @ of 150kg of SSP per acre was applied. In addition, it was top dressed with within 20-30 days of rice transplantation @ 60kg/ acre. After 15 days of paddy transplantation, the fingerlings were introduced. This gap was maintained to prevent damage of freshly transplanted rice by fish especially Grass Carp. The fish were harvested few days (3-5 days) before paddy harvest to dry the plot for the rice harvest.

Feeding Arrangements

Grass Carp feeds on phytoplanktons that are grown in the rice field and Common Carp being omnivorous and bottom foraging fish; mostly feed both on phytoplankton and to lesser extend on zooplanktons. Manure / fertilise application was therefore applied in the field from time to time for maintaining sufficient growth of these planktons. Fish were also supplemented with 3 kg of feed per week consisting of maize grit, rice bran and oilcakes. About 2 kg fresh fodder leaves (Ficus, Napier, Alfalfa and White clover) was also supplemented with the feed weekly. The water temperature to 15° C and about knee high water level were regulated for faster growth of fish as well as the planktons. The unwanted aquatic weeds like *Monochoria vaginalis*, *Cyperus difformis*, *Schoenoplectus juncooides*, *Echinichloa crus-galli* (Chris Parker, 1992, Weeds of Bhutan) were removed manually to facilitate free movement of fish.

RESULTS

Comparative Fish Yield

It was observed that the growth rate of Common carp was found to be much faster and higher than the Grass carp. The Common carp weighed between 170 gm to 410 gm compared Grass Carp which weighed 30-80 gm in a period of three months. Further it was noted that their growth rate was optimal and overall survivability was found to be to be better than Grass carp.

Some degree of predation by aquatic birds was noticed which was beyond our capacity to control it. Some fingerlings were found to have escaped through the holes of the bunds made by insects and rodents especially during night time that ultimately contributed to over loss. However during the entire trial period no major mortality and diseases occurrences were observed.

The first trial was terminated on 20 October 2004 and the fishes were harvested one week prior to paddy harvest and weighed. In total Common carp yielded 11.2 kg compared to 3.5 kg from Grass carp.

During the second year of experiment, the yearlings were used instead of fingerlings. About 200 each of Common Carp and Grass Carp were released in the field. The fishes were harvested at 110 days of growth period in the rice field. On the day of harvest, 95 percent survival was recorded of Common Carp weighing 15 kg in total with an average weight of 79 gm each. Low survival rate of 30 percent from Grass Carp was recorded on the day of harvest. The average weight was 100 gm each weighing 3 Kg of total production from Grass carp as indicated in Table 1.

Table 1: Fish species, quantity and yield of two years experiments

Fish species	Year 1		Year 2	
	N (number of observation)	Average weight	n	Average weight
Common Carp	6	170-410 gm*	190	79 gm
Grass Carp 100 gm	6	30-80 gm*		60

Note: weight in range; counting was not done at the time of harvest to derive the average weight

Comparative Rice Yield Assessment

The paddy yield from treatment and control plots were assessed and quantified. It was observed that on an average, rice yield was higher from plot where Common Carp was introduced (8 t/ha) compared to Grass Carp plot (5.8 t/ha) as indicated in Table 2. Rice production was also higher from Common Carp introduction plot (8 t/ha) compared to control plot without fish culture (5.8 t/ha).

Table 2: Rice yields of two-year experiments

Experiment plots	Average yield (T/Ha) Year 1	Average Yield (T/Ha) Year 2	Mean
Common Carp plot	7.5	8.3	8
Grass Carp Plot	5.0	6.6	5.8
Control plot	6.4	5.2	5.8

Looking at yield differences with and without treatments, the findings indicated that it is economical and advantageous in growing rice through introduction of Common Carp fish species than as mono crop under Bajo's conditions. Even though the paddy yield was much lower where Grass Carp was introduced. However, it had an additional advantage of fish harvest and *Sochum* (*Potamogeton distinctus*) weed being controlled to a large extent because of its feeding habitat. Though there was no yield difference in the plots of Grass Carp and the Control plot but still the plot with Grass Carp had higher economic return compared to the Control plot without fish. Also it had been indicative that the yield from the Grass plot was comparative to Control plot yield even beside the feeding habit of Grass Carp on rice plants.

Economics of Rice-Fish Culture with Rice as Monoculture: A Simple Cost Benefit Analysis

The findings (in Table 3) revealed that the return from the rice-fish culture was higher compared to rice as monoculture. The rice-fish plot with Common carp yielded highest both in terms of paddy production and fish yield followed by Grass carp. The comparative finding is very apparent from Grass carp plot and Control plot paddy yield. Though the paddy yields were same but in terms of gross return, the Grass carp with rice appears better economically. There is greater assurance from fish harvest even during the time of crop failure due to natural calamities. Therefore, polyculture maximises production compared to monoculture.

Table 3. Simple economic analysis of rice-fish culture with rice as mono-crop.

Treatments	Rough rice		Sale of rough rice	Fish		Sale of fish	Gross Income (Rice + Fish)
	Yield, Kg	Rate		yield (kg)	Rate		
Common Carp plot	237	12/Kg	2844	13	85/Kg	1105	3949
Grass Carp plot	174		2088	3.25		276	2364
Control Plot	174		2088	00		00	2088

Effective Shochum (*Potamogeton Distinctus*) Control by Fish

Common weed of rice known as Shochum infests paddy resulting in decline in rice yield in west and west-central region. This very weed is a type of phytoplanktons that Grass Carp nourishes. One of the aims of introducing fish in rice was to study the feeding habits of Grass Carp on this weed and in the trial plot where Grass Carp species was introduced there Shochum was not seen indicating that Grass Carp species is a selective forager and eats Sochum available in the rice field.

Problems Encountered

- The main problem encountered was the regulation of water level in the rice field. The water level had to be continuously monitored as the rodents and insects made holes through which the water sieved resulting into low water level in the rice field. The low level of water in the field also checked the moment of fish in the rice field.
- The other problem was the predation of fish mostly Grass Carp by the aquatic birds resulted into low Grass Carp yield at the end of the experiment.
- It was also observed that if the fish are introduced too early the Grass Carp were tempted to eat freshly transplanted rice plant. The problem was serious on introducing Grass Carp yearlings. This might be attributed to low rice yield at the end of the experiment.
- Size of fish harvested was small due to short growth period
- The present status of rice-fish culture is very unsatisfactory due to poor extension activities and the cultural system being new to the people.

CONCLUSION

Although economic analysis was not done, rice fish culture seems to be viable in in the rice growing areas with perennial irrigation system. Rice yield seems to increase with rice-fish culture especially with grass carp and control of weed is also possible and fish can be harvested from the same field for utilisation of the land. Therefore, such activities should be strengthened to accelerate the prospect of rice-fish culture system in future. However, this information could be validated further by conducting similar experiments at farmers' field to draw strong recommendations on this integrated farming approach at the wider scale. It is expected that this study would also help to some extent to those interested to opt such polyculture production system to boost their production and income.

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The author wishes to deeply acknowledge the Director, Department of Livestock for granting the permission to carryout this trial in Bajo. The author would also like to thank the Management of Warm Water Fishery Centre, Gaylegphu for sparing the fingerlings and yearlings on cost free basis to execute the trial on time. Those who contributed to the original papers, through typing, editing, comments and criticism, are too numerous to name; but I thank them all. Finally, I am greatly indebted to the Program Director, RNRRC Bajo for his support and guidance in successfully implementing and completing this trial.

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Align the figures horizontally
Put captions below the figures; 10 point bold italics
Abbreviate figure to fig

References:

The literature references should be arranged alphabetically, typed single 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 a. 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.

Refer to unpublished work only in the text, in this manner: (U. Wangchuk, unpublished), (T. Wangchuk, personal communication.).

References should contain: author's last name followed by author's initial(s) (no 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 of REFERENCES

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

Dorji, Tenzin (1995). Assessment of non-timber forest resource utilization in Eastern Bhutan. Field document no.UTF/BHU/008/BHU/. Third Forestry Development Project.Forestry Services Division, Thimphu

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

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