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Crop Genetic Resources for Food Security and Adaptation to Climate Change: A Review and Way Forward

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Abstract

Agricultural biodiversity is the primary basis for food production and a potential resource for adaptation to climate change. The genetic makeup of crops determines their inherent ability to adjust to changing environments such as extreme temperature, soil nutrient deficiencies, varying rainfall patterns, drought and pest and disease. Crop genetic resources will serve as the primary source for development of resilient crop varieties to cope with negative impacts of climate change. Bhutan's national agricultural research system has considerably relied on the use of improved crop varieties for increasing production. It is estimated that over 60% of the time and resources of the Renewable Natural Resources Research and Development Centres of the Department of Agriculture is allocated to germplasm adaptation, improvement and management. However, the turnover and delivery of crop varieties from introduction and selection, conventional breeding and recombination programs have been quite slow. Conscious breeding and selection for climate resilient crop varieties has received less attention which can be attributed to the lack of awareness, training and expertise on the issues related to climate change. More emphasis should be given to strengthen crop improvement programs that are focussed to meet the emerging challenges of climate change.

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Keywords: Climate Change; germplasm; climate resilient crop varieties

1. Introduction

Bhutan possesses rich crop genetic resources, both wild and domestic, which has significance at the regional and global levels. Agricultural biodiversity is a primary resource for adaption to the changing climate as the genetic makeup determines the tolerance of crops to extreme temperature shocks, nutrient deficiencies, varying rainfall patterns, and drought, incidence of pest and diseases and adjustment to unique agro-ecological systems. Bhutan has diverse agro-ecological zones ranging from hot and humid sub-tropical zone to the cool alpine zone which has helped to create both natural and agricultural diversity. A self-sustaining and

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subsistence agricultural production system with small land holdings where farmers grow a variety of crops to meet their needs has resulted in a rich on-farm agro-biodiversity. Some of the traditional crops and varieties have adapted perfectly to their specific environments making it nearly impossible to replace them with parallel alternatives. Some of the crops and varieties are grown for very specific domestic consumption and spiritual needs. It is in this context that research and development has to focus on the development, utilization and conservation of crop genetic resources that can help adapt to the impacts of changing climate for food and nutritional security. Capitalizing on available crop genetic resources, utilizing farmers' indigenous knowledge on these rare crops and species and backed up by modern scientific technologies can serve as a natural insurance against the impending impacts of global climate change on agriculture and food security.

Crop genetic resources will serve as the sources of development of resilient crop varieties to cope with negative impacts of climate change. There is therefore an urgent need to gainfully exploit the available crop genetic resources to adapt to climate change and increased food production instead of merely focusing on conservation and maintenance of diversity. This remains a major challenge and will require the major overhauling of the current agriculture research and development institutions to understand and transform their programs towards developing a more productive, climate smart agriculture system in the back drop of changing climate for enhancing food and nutritional security.

2. Materials and Method

This working paper on crop genetic resources was prepared to contribute towards developing the national food security paper for the Department of Agriculture (DoA) for the first Bhutan Climate Summit 2011. Food security and climate change was one of the focuses of this regional climate summit for a living Himalayas. A team undertook a comprehensive review of the on-going research, development, conservation and utilization interventions on agro-biodiversity resources in the country. The literature review looked at the status of the domestic diversity of food and horticultural crops followed by the research and development projects on crop breeding and germplasm evaluation. In doing so, the research focus on climate science and specific consideration for adaptation to climate

related factors were analysed. The existing strengths and weaknesses of the institutions associated with agro-biodiversity, crop improvement and adaption of crop varieties were assessed. The technical capacity to realign the ongoing research to the climate change related challenges that could directly affect the household food security of the poor farmers was reviewed. Based on the outcome of the review a set of recommendations have been proposed.

2.1 Situational analysis

Domestic diversity has been the primary source of food production for the Bhutanese. Bhutan's location as a landlocked country in the high Himalayas, poor accessibility and its relative isolation from other parts of the continent have made it dependent on domestic food production, livestock and products collected from the natural forest. In essence the domestic diversity has been the main source of food for centuries. The current richness in the domestic diversity of species and varieties is enhanced through the process of natural and human selection. Variability in altitudes and climate has allowed the Bhutanese farmers to cultivate a wide range of food crops, vegetables and fruits. The local crops have considerable genetic diversity and are well adapted to the specific requirements of the areas where they are grown.

Bhutan is known to harbour over 7000 species of vascular plants many of which include fruits, vegetables and cereal crops that are native, invasive, ecological escapes or introduced long ago and have adapted with unique genetic, morphological and ecological characteristics (BAP, 2002). In the agricultural crops some 80 different species are estimated to be found in the country. Bhutanese farmers are known to grow and maintain a diverse range of local varieties in their fields to meet different needs. A wide variety of horticultural crops and vegetables are cultivated. Potato, citrus, apple and cardamom are major cash crops that are cultivated at a commercial scale. All households in Bhutan maintain vegetable gardens in their backyards to grow a mixture of vegetables and herbs to meet their daily requirements. A variety of vegetables and fruits are also collected from the wild. A brief description of the diversity of cereals, fruit crops and vegetables and their status are discussed below.

2.2 Cereals, oilseeds and grain legumes

Rice, maize, wheat, barley, buckwheat and millets are the major cereal crops cultivated. In addition to these major crops there are also a number of minor and underexploited crops that are cultivated by farmers in small scale. Upland rice, foxtail millet, little millet, amaranths, pyrilla, oilseeds and grain legumes constitute some of these crops. It is estimated that there are about 350 landraces of rice, 47 of maize, 24 of Wheat and 30 of Barley in the country (BAP, 2009). Rice is by far the most important food crop of Bhutan and it is grown from tropical lowlands (200 m) in the south up to elevations as high as 2700 m in the north. The native rice varieties possess significant genetic and ecological diversity. The total rice area in the country is estimated to be around 22,550 ha (DoA Stats, 2010), almost all of which is irrigated. The average national rice yield is about 3.18 t/ha. The overall self-sufficiency in domestic rice production is only about 48% (PPD, 2011). One of the cherished goals of the Royal Government is to increase the self-sufficiency level in rice food production. More than 65% of the total rice area in the country is still planted to traditional varieties (Shrestha, 2004), reflecting the high adaptability and suitability of these cultivars in the traditional farming systems.

Maize, another important staple, is cultivated in all the 20 districts ranging from 200 m to nearly upto 3000 m asl. There are several landraces which are recognizable by their distinctive morphological traits. Farmers have different names for the local cultivars which have well established adaptation to micro-climate, soil types, and time of sowing and other climatic properties. Such landraces are genetically diverse, although they may be similar phenotypically. However, detailed studies at the genetic or molecular level are lacking. About 51% of the maize area is planted to traditional varieties (Shrestha, 2006). Wheat, third most important cereal after rice and maize, is grown in almost all the different agro-ecological regions of the country, from about 200 m to locations above 3000 m as a main or secondary crop after rice and potato, and in rotation with buckwheat at higher altitudes. Wheat landraces are perhaps the most threatened cereal food crops in the country.

Oilseeds constitute major agricultural crops in the country next to cereals. Predominant oilseed crops are mustard and rapeseed (*Brassica juncea* and *B. campestris*) grown at altitudes from about 200 m to 3000 m. The acreage under oilseed crop is slowly diminishing because it is not

economically viable. In addition to *Brassica* species, there are other oil-bearing crops grown traditionally. Sesame (*Sesamum indica*), Nigra (*Brassica nigra*) sunflower (*Helianthus annuus*), Soybean (*Glycine max*) and groundnut (*Arachis hypogea*) are other oilseeds species cultivated in the eastern parts of the country. There are also a number of perennial oil-bearing trees from which seeds are harvested to extract oil. These include Pangtsi (*Symplocus paniculata*), Yika (*Maduca butyretica*), Karshing or Kadam (*Jatropha curcas*) and Shingshe (*Neolitsea* sp).

Legumes are important component of the farming system mainly in the mid and low altitudes. Legumes cultivated in the country can be grouped as grain legumes, vegetable legumes, fodder and green manure legumes. The popular grain legumes comprise of soybean (*Glycine max*), kidney beans (*Phaseolus vulgaris*) mungbean (*Vigna radiata)*, cow pea (*Vigna unguiculata*), Urd bean or black gram (*Vigna mungo*) and rice bean (*Vigna umbellata)*. Beside this groundnut (*Arachis hypogea)* and pigeon pea (*Cajanus Cajan)* are also gaining popularity. Common Bean (*Phaseolous vulgaris*) and peas (*Pisum sativum*) are the two most important vegetable legumes. A variety of exotic fodder legumes are also promoted by the livestock sector. Dhaincha (*Sesbania aculeata)* is a popular green manure legume. Traditional varieties reported and the number of improved varieties released formally is reported in Table 1.

Due to changing weather patterns, humidity and temperatures there has been a dramatic rise in pest and disease outbreaks in many crops. In maize, two devastating fungal diseases, Turcicum Leaf Blight (TLB) and Gray Leaf Spot (GLS) have caused huge losses in maize production. GLS was previously not reported in Bhutan and Bhutanese maize farmers in the Highland (>1800 m asl) and Sub-tropical Zone II (> 1200 m asl) are facing a new, extremely serious problem of this disease (De Leon, 2007). This new disease that occurred in epidemic scale in 13 Dzongkhags affecting 4,193 households causing a production loss of 6,504.12 MT (DoA**,**2007). Likewise in rice, a major epidemic outbreak of blast disease occurred in 1995 in warm temperate rice growing areas leading to a loss of 1099 MT of rice or Nu.11 million (MoA,1995). The blast disease unique to the sub-tropical rice which is associated with high rainfall and overcast conditions was recorded in the warm temperate rice ecosystem. With unpredictable and extreme weather patterns, such occurrences of new diseases and pests are only to rise in the future.

Table 1. Status of the important cereals and legumes

Categories	Crop	No. of traditional varieties	No. of varieties on decline	No. of improved varieties released	Remarks
Cereals	Rice	285	55	23	The number of traditional varieties recorded is reported by farmers. They have not been characterized phenotypically or morphologically
	Upland rice	14	14	1	
	Maize	58	38	5	
	Wheat	21	15	3	
	Millet	69	25	2	
	Barley	21	18	0	
	Buckwheat	23	14	0	
Oilseeds	Mustard	19	12	4	
Legumes	Beans	51	22	7	
	Peas	7	3	3	
	Soybean	20	9	3	
	Vigna sp	20	2	2	

Source: NBC, 2008

2.3 Horticultural crops

Food security exists when people have the access to safe and nutritious food at all times. Climate change directly affects food security because the food production system directly depends on the variability of weather. A diversified food production system with the integration of horticulture crops can offer better dietary diversity and nutritional security as compared to the mono cereal based system. Horticulture, thus offers an immense potential for enhancing food and nutrition security by ensuring household income from sale of produce, choices of vegetables crops which can supply valuable vitamins and minerals for human nutrition and can provide dietary diversity. The prevalence of diverse agro-climatic conditions favours cultivation of different fruits, nuts and vegetables. The major horticulture crops are root and tuber crops, temperate fruits and nut, subtropical fruits and vegetables. Horticulture crops fits well in the steep slopes that are highly prone to soil nutrient loss and degradation. It also offer good scope for diversification of production system and land use

intensification through multi-storeyed cropping patterns with seasonal crops cultivated beneath the tree crops.

2.3.1 Root and Tuber Crops

Potato is the most important crop under this category. It was introduced into the country in the late sixteenth century (Roder and Gurung, 1990). Today, it is a major cash crop and export earner for the country. Desiree, Kufri Jyoti and Yusikaap are the three predominant varieties in the country. They are recommended for general cultivation for all the cropping systems in the different agro-ecozones. Desiree, a red skin, early maturing Dutch variety is by far the most preferred variety despite its susceptibility to late blight and relatively lower yield. Kufri Jyoti, an Indian variety and Yusikaap originally an Argentinian variety called Achirana INTA (CIP Accession No. 720088) both have white skin and are medium in maturity (90-120 days) with moderate resistance to late blight. Desiree is speculated to have been introduced in 1970 and Kufri Jyoti in 1978 for general cultivation prior to the inception of the potato program, however, their releases were formalised only in 1988. Yusikaap was introduced in 1981 and released in 1988 after rigorous testing. In addition to the three predominant varieties a few old varieties such as Maritta, Cosima, Tasso, Magnum Bonum and Darjeeling Red Round, Hazarey and Bombay White are still grown in small acreage (Gurung, 1991). Another white skin variety Khangma Kaap (CIP 378015.13) was released by RNR RDC Wengkhar in 2002. There are also a number of other tuber crops like sweet potato (*Ipomea batatus*), Tapioca *(Manihot esculenta)* and Yam (*Dioscorea* spp). Potato, a very important crop has a very narrow genetic base of four commercial varieties. There is an urgency to scale up introduction and evaluation of pest, diseases and stress tolerant varieties in the country.

2.3.2 Temperate fruits and nuts

Apple is the most important temperate fruit, grown between altitudes ranging from 2000 m to 3000 m asl. Commercial varieties popularly grown are Red and Golden Delicious, which are preferred by the growers, consumers and exporters for their sweetness, size and fruit colour. Recently, many other apple varieties have also been introduced mostly from Europe, Japan and India. Besides apple and peaches, Chinese pear (*Pyrus pyrifolia*) is an important traditional fruit crop. Chinese pear was traditionally more important than apple because it did better at higher

altitudes than apple. Walnut is another important crop in the temperate areas. The native walnut (*Juglans regia*) is hard-shelled and difficult to crack. Other important crops are hazelnuts, apricots, pecan, chestnut, almond, pears, plums and a host of berries. A number of exotic fruits and nuts have been introduced including soft-shell walnut, apricot, peaches, plums, cherry, almonds, pecans and different berries.

2.3.3 Subtropical fruit crops

The subtropical fruit zone stretches from about 400 m to above 1600 m, where a number of crops are grown. Among these, mandarin (*Citrus reticulata*) is the most important crop in terms of area and income. It can be estimated that over 90% of citrus area is planted to local mandarin. The diversity of the local mandarin seems to be limited in the absence of any systematic studies. The Ministry of Agriculture is therefore providing options through the introduction of different citrus species mostly from Europe, Japan, USA and Australia. Besides citrus, other subtropical fruits such as avocado, mango, guava, banana, grapes and pomegranate are also introduced and popularized.

2.3.4 Vegetables

Given the diversity of agro-climatic conditions, a wide array of vegetables are grown in different parts of the country. A lot of these vegetables are relatively new for Bhutan, having been introduced and promoted by the Ministry of Agriculture from the 1970s. Some of the traditional vegetables, however, are chilli, radish, turnip, pumpkins, squashes, leafy greens and different gourds. The relatively recent introductions include carrot, tomato, cole crops and asparagus. In addition to the cultivated vegetables Bhutanese also harvest several plants from the wild and consume them as vegetables. The popular wild collections include wild edible mushrooms, bamboo shoots, ferns, orchids, cane shoots, wild asparagus, wild onion, stinging nettle and different yams.

Diversification of the food production system helps in coping with the risk of climate change on food and nutrition security. Promotion of horticulture industry can help diversify food production, enhance household income and provide dietary diversity which ensures more resilience to food and nutrition security. Further the opportunity to earn cash from sale of horticultural produces can help buffer seasonal food shortages by improving the access to food.

3. Results and Discussion

Having reviewed the status of the domestic diversity and the introduced varieties for both field crops and horticultural crops, other aspects of crop improvement and adaptation are elaborately discussed below in light of the need to realign the ongoing focus of crop improvements programs on climate change.

3.1 Crop Improvement and Development

Crop breeding has been recognized as one of the proven means to overcome abiotic stresses for accelerating food production. It will remain as one of the most sustainable means to adapt to the progressively changing climate which manifest in the form of shifting rain fall patterns, droughts, cold wave, early frost and insurgence of diseases. Improved varieties, through their higher yield potential and ability to resist pest and disease have played a fundamental role in increasing productivity in the developing countries in the past and it still remains a potential means to raise production (Byerlee, 1994)

In Bhutan introduction and selection of crop varieties have received a very high priority even since the systematic and organized agricultural research started in 1982. However, conscious breeding and selection for climate resilient varieties has received less attention. This is mostly because of lack of awareness, training and expertise on climate change related science and knowledge. At present there are four RNR Research and Development Centres (RNR RDC) at Bajo, Wengkhar, Bhur and Yusipang which carry out research on food crops and horticulture. Almost over 80% of the time and resources of RNR RDCS is allocated to germplasm adaptation, improvement and management. Further value addition in terms of research and development in terms of upgrading skills and knowledge on climate change issues and aligning research in this area will be crucial. RNR RDCS are the main institutions responsible for development, adaptation and maintenance of crop genetic resources. The CGIAR centres like IRRI, CIMMYT, CIP, AVRDC, ICRISAT, ICARDA and National Agriculture Research Centers in the region have been the main sources of crop germplasm. The RNR RDCs are engaged also in improving local crops and their varieties through seed selection, cross breeding and selection, crop competitions and seed fairs. The focus is on important food

crops such as rice and maize. Improved crop varieties of cereals and different other horticulture crops released so far is presented in Table 2.

Table 2. Number of released varieties of cereals, fruits and vegetables

Categories	**Crop**	**No. of improved varieties released**
Cereals	Rice	23
	Upland rice	1
	Maize	5
	Wheat	3
	Millet	2
Oilseeds	Mustard	4
Legumes	Soybean	3
	Mung bean	2
Fruits	Citrus	6
	Apple	6
	Walnut	2
	Apricot	1
	Peach	3
	Pear	4
	Sub tropical Apple	1
	Lime	3
	Persimmon	1
Vegetables	Chilli	3
	Radish	3
	Mustard Green	3
	Strawberry	3
	Cauliflower	3
	Carrot	2
	Tomato	2
	Pumpkin	2
	Onion	1
	Cabbage	1
	Beans	2
	Pea	2
	Water Melon	1
	Potato	4
Medicinal and Aromatic plants	Cardamom	2

Source: Impact Assessment of Horticulture in Bhutan, 2009

3.1.1 Breeding for climate resilient crop varieties

Hybridisation of traditional Bhutanese rice cultivars with improved varieties or lines was started in the mid 1980s as a longer-term strategy for the improvement of Bhutanese indigenous rice varieties. The Bhutanese rice varieties are low yielding as response to added inputs is limited by lodging and disease manifestation. However, they are valued for their yield stability and grain quality. The principal objective of the cross breeding programme is to assimilate desirable genes for high yield, adaptability, grain quality, cold tolerance and disease resistance from various sources.

To date, over 150 crosses have been made involving traditional varieties of Bhutan and improved breeding lines and/or varieties from elsewhere (Ghimiray, 2001). More than 60 popularly grown varieties from

Table 3. Climate resilient rice varieties developed by RDCs

Variety	Parents	Year released	Developed by	Altitudes (m)
Bajo Maap 1	Local Maap/IR 64	1999	RDC Bajo	600-1500
Bajo Maap 2	Local Maap/IR 64	1999	RDC Bajo	600-1500
Bajo Kaap 1	Paro Maap/IR41996	1999	RDC Bajo	600-1500
Bajo Kaap 2	Bja Naab/IR41996	1999	RDC Bajo	600-1500
Yusi Ray Maap1	Suweon 359//IR41996-118-2-13/Thimphu Maap	2002	RDC Yusipang	Above 1800
Yusi Ray Kaap1	YR3825-11-3-2-1/YR3825-11-3-2-1/Barkat	2002	RDC Yusipang	Above 1800
Yusi Raykaap 2	Akiyutaka/Naam	2010	RDC Yusipang	>1800 m
Yusi Raymaap 2	Akiyutaka/Rey Maap	2010	RDC Yusipang	>1800 m

Source: Ghimiray, 2010

the high and mid-altitude rice growing zones were used as local parents. RDCs have cross bred and developed several rice varieties (Table 3) which are more adapted to local conditions. These developments have come about without deliberate understanding of climate change issues, however future efforts can be pursued more vigorously rooted in climate change science and adaptive strategies.

The majority of the rice areas in the flatter southern foothills are rainfed and subject to the vagaries of changing climate manifest in the form

of onset of monsoon (early or delayed), insurgence of new diseases, and amount of rainfall (drought or flash floods). It is vital that drought tolerant rainfed rice varieties are grown under such conditions to minimize risk of crop failure. The research centre at Bhur has evaluated and released two rainfed rice varieties (Bhur Kambja 1 and Bhur Kambja 2) in 2010 for the first time in its research and development history. This reflects the importance and need for climate change risk management in the agriculture sector.

Insurgence of new disease and its spread is an expected effect of climate change. Development and adaptation of crop varieties continues to be the most sustainable option to manage disease epidemics. In 1995 rice blast, a disease most prevalent in sub tropics caused by *Pyrcularia grisea* occurred in epidemic scale in high altitude rice growing areas above 1800 m asl severely affecting all the traditional rice varieties. The release of blast tolerant rice varieties like Khangma Maap was the most sustainable option to contain the disease. Similarly in maize, Gray Leaf Spot (GLS), a disease never reported in Bhutan was confirmed in 2007 at elevation above 1800 m asl. It is unique for this disease often prevalent in the coffee growing areas reported at such elevation. To respond to this disease the maize program introduced several genotypes from different sources and has identified and released two tolerant varieties S03TLYQAB05 (Shafangma Ashom) and ICAV 305 (Chaskarpa) to the farmers. In citrus, citrus greening disease *(Huanglongbing)* caused by *Liberibacter asiaticus* remains a serious threat.

Despite the earnest efforts of RNR RDCS, the turnover of crop varieties from conventional shuttle breeding and recombination has been quite slow. A way forward would be to develop proposals for collaborative breeding programs with CGIAR centers that will allow the use of modern breeding techniques including Marker Assisted Selection (MAS). For this to happen, basic laboratory facilities need to be established in RDCs and scientists and technicians trained to run the programs. Projects should be developed in consultation with CGIAR centres and donor funds secured.

3.2 Institutions and capacity building

The history of agricultural research in Bhutan is fairly short having started only in 1982 with the primary mandate of solving farmers' immediate needs. It started with introducing exotic crop varieties and bringing about changes in cultivation methods to increase production. Hence minimum resources in terms of research facilities and manpower

were required then. Initially, it succeeded well but it failed to keep pace with emerging challenges and issues, climate change in particular.

Among the existing institutions, RNR RDCs are the oldest dealing with crop improvement research. The National Biodiversity Center (NBC), created in 1998, serves as the focal centre for Plant Genetic Resources (PGR) and conservation of biological resources. However, RNR RDCs under the Department of Agriculture are actively involved in development and utilization of crop genetic resources in field crops and horticulture. RDCs are assigned specific commodities such as rice, maize, fruits and vegetables to lead research and development of those commodities. RDCs also maintain small germplasm collections and tree mother blocks for their use. The National Seed Center (NSC) also handles large amount of crop germplasm including that of potato. Synergy among institutions is much desired.

In order to face the climate change challenges, there is a need to refurbish the existing conventional research system with adequate research infrastructures, facilities and equip its human resource with latest skills and expertise. A review of the present research facilities should be carried out to ascertain the adequacy of dealing with new challenges. Up-gradation of the existing facilities is long overdue. Basic modern tools and techniques in crop breeding and improvement such as Polymerase chain reaction (PCR) and Marker Assisted Selection (MAS) needs to be put in place and people trained to use them. Inadequate manpower and technical skills in crop breeding and germplasm utilization remain a serious impediment. There is a serious lack of awareness, education and information on climate change issues and possible remedial measures among the present research scientists as well as the agricultural extension personnel. A good starting point would be to organize sensitization and education campaigns.

3.3 Information management and knowledge sharing on climate change and crop germplasm

Climate change is associated with increasing uncertainty and variability. Generation of relevant information pertaining to agriculture, its availability and dissemination to the farmers is imperative in the face of the climate change. Farmers whose food security is the most vulnerable to the impact of climate change need right information to make short and long term decisions to adjust their farming practices, choices of crops and other technologies. Climate related information has to be generated from relevant

institutions. At present there is no such institution that can provide adequate and sound climate related information services to the farmers.

Basic information on crops and horticulture germplasm is not systematically catalogued and updated. The little available knowledge is often with an institution or sometime even with individuals. Cataloguing of information in the right form remains a priority to upscale future work on germplasm. Our farmers have a wealth of knowledge on different crop varieties, their management, adaptability and use. Such indigenous knowledge is not documented or utilised. There is no information available on the different farming systems practiced in the different agro-ecological zones. Although there is a general understanding of the various types of farming practised, detailed study will help in capturing in-depth requirements of a particular system. Unless this is done suitable crop varieties cannot be developed. In addition, farmers' crop genetic resources should be documented.

The available information has to be disseminated to the farmers in the shortest possible time and has to be communicated in the simplest form which they can comprehend. In the present set up, the existing extension system is the main conduit for disseminating the information. This existing system however has many problems owing to the large coverage of remote areas, lack of technical skills and resources. The existing information dissemination systems needs major revamping and should take advantage of the modern communication facilities to link to the farming communities. A more engaging institution to coordinate the processing, packaging and dissemination of information could be the way forward.

Farmer's forums and media can be effective way to share the useful information on unique crop varieties. There also a need to create awareness among stakeholders engaged in germplasm development and utilization on the recent international treaties and agreements such as Standard Material Transfer Agreements, Cartegena Protocol, and ITPGFRA.

4. Findings and suggestion

Agriculture sector and the farming communities in particular are the most vulnerable to climate change. Higher temperatures eventually reduce yields of desirable crops besides favouring the proliferation of weeds and pests. Changes in precipitation patterns increase the likelihood of crop failures and long-run production declines (IFRI, 2009). This sector however

continues to work in isolation from the climate related issues. There is acute lack information on progressive climate change and no use of climate data in agriculture planning, research and development. As in most South Asian countries the responsibility for climate change rest with the environmental sector which dilutes the focus on agriculture. At present there is no designated institution in the Ministry of Agriculture and Forest that provides climate information services for agriculture. There is also no adequate capacity for analysis and dissemination of climate science data for agriculture research and development. There is an urgent need to designate and develop an institution within MoAF to help realign the ongoing conventional agricultural programs to be more climate-sensitive.

Strengthening the present crop improvement programs of the national agricultural research system would be a good entry point to lay the foundation for food security amidst changing climate and resultant impacts. A higher priority should be given to crop breeding and improvement programs that are sufficiently aligned to meet the challenges of climate risks. An immediate thrust of research and development has to be on the effective utilization of available crop genetic resources that will add value and contribute to food security. In order to achieve this, institutions have to be strengthened, infrastructure developed wherever necessary and research facilities built to enable high quality research outputs. The calibre and technical expertise of researchers as well as extension personnel on climate variability, risks and impacts need to be improved through appropriate human resource development programs. Collaboration and partnerships with regional and international centres of excellence for crop improvement (IRRI, CIMMYT, CIP, ICRISAT, ICARDA, AVRDC etc) and institutions having experience and expertise on climate science need to be forged. Research proposals should be developed to attract donor funds for research and capacity improvement.

4.1. Improvement of the availability Climate data and information gap on climate science

Agriculture continues to play the most critical role for food security and poverty alleviation in Bhutan. Agriculture therefore has to undergo significant transformation in order to meet the challenges of food security and climate change. However, agriculture policy makers, researchers, extension workers and farmers are least equipped with the data, information and knowledge on climate change. In light of this there an urgent need for:

- Designate and capacitate an institution within the Ministry of Agriculture and Forestry that can provide climate information service for agriculture planning, research and development. It should be mandated to liaise and link agriculture programs to climate change and coordinate the work on climate science
- Consolidate, analyse and provide climate data for agriculture planning, research and development
- Enhance capacity of policy makers, agricultural planner, researchers, extension and farmers on climate science
- Coordinate the dissemination and sharing of information on climate change for developing more climate resilient agricultural production system with higher productivity for enhancing food security
- Undertake awareness, education and advocacy on climate risks
- Organize awareness, education and advocacy campaigns at different levels (scientists, extensionists, farmers, policy makers) on food security and climate challenges
- Use public media for effective information dissemination

4.2 Crop Improvement and Germplasm utilization to focus on climate risks

- Develop climate smart production system with accelerated adaptation, higher productivity and resilience that can better adapt to progressive climate change
- Prioritize and prepare action plan for types of agriculture research to be undertaken for transformation of present agriculture production system to more resilient production system for food security and climate change
- Provide additional impetus to the program by strengthening the present setup, infrastructure, facilities and manpower
- Align the research and development programs to climate science especially by using empirical climate data to develop technologies that can directly help adapt against the challenges arising from climate change and its impacts
- Document farmers' indigenous knowledge on crops and production technologies and feed this information into modern crop improvement programs

- Upscale the genetic by environment (GxE) trials at different environments with application of scientific climate data; intensify Participatory Plant Breeding (PPB) and Participatory Variety Selection (PVS) for selecting climate resilient crop varieties
- Collect, conserve, characterize and utilize local diversity of field crops and horticultural crops in crop improvement programs
- Develop and promote efficient post harvest technologies with the principle of lose less and feed more and to ensure availability of nutritious food and income throughout the season

4.3 Development of an efficient seed system

- Limited availability of seeds and planting materials is a major factor for slackening the dissemination of germplasm to the farmers.
- Promote efficient seed production and supply systems (both formal and informal) to ensure rapid access to improved varieties by the farmers
- Promote community based seed production system by promoting community seed banks, seed clubs and farmers group to facilitate the faster dissemination and delivery of technologies

4.4. Institutions and research facilities for crop improvement

- Review existing infrastructure and research facilities in the light of emerging needs and level of sophistication
- Propose additional facilities, laboratories and equipment (PCR, biotechnology) wherever necessary for quality research outputs
- Introduce modern crop breeding techniques such as MAS to ensure faster and reliable results/outputs

4.5. Capacity building for strengthening crop improvement program

- Review existing human resource in the field crops and horticulture sectors in terms of numbers, qualifications and disciplines in light of emerging climate related issue s
- Redeploy existing human resources and recruit additional manpower wherever required
- Develop a human resource master plan in the light of food security goals of the Ministry and implement it

- Retrain agricultural researchers and extensionists on food security and climate science through training, exposure visits, workshops

4.6. Links with centres of excellence and donors for accessing advanced and improved germplasm

- Develop, formalize and maintain linkages with CGIAR centres, National Agricultural Research centres and other centres of excellence for effective sharing of genetic materials, information, technologies and expertise
- Develop good research project proposals and seek donor funding to pursue work on all aspects of food security such as developing new crop varieties that are climate resilient for different agro-ecologies, and dissemination of technologies. In doing so, utilize climate science data consciously.

5. Conclusion

Bhutan's agriculture is still largely subsistence where the use of inorganic inputs and sophisticated technologies are minimal. The rugged terrain and the economic status of the farmers do not favour the large scale adoption of modern farming. To adapt and mitigate adapt to the ensuing threats of climate change, Bhutan's agriculture system has to be climate smart. One of the sustainable ways to move towards climate smart agriculture would be to gainfully exploit and use the available crop genetic resources. Evaluation and adaptation crop varieties resistant to biotic and a-biotic stresses including drought, heat, frost, hailstorm, and pests and diseases should be given a very high priority. Crop improvement programs should therefore focus on developing more climate resilient crop varieties for food and cash crops for all agro-ecozones.

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Grain yield as affected by time of transplanting in mechanized rice farming in Wangdue-Punakha Valley

Ngawang Chhogyel[2], Legjay, Tshering Dema, Nima Tshering

Abstract

An experiment to determine the effects of different transplanting times on grain yield of machine transplanted rice was conducted at Lobesa, Punakha in 2012 season. Rice was transplanted on three different times (23 June, 7 July and 23 July) using transplanters. Twenty one day old seedlings raised in tray nurseries were transplanted at three different dates. Cultural management practices such as irrigation, fertilization and weeding operations were carried out as routine management. Regular monitoring of crop was done for incidences of diseases and pests. At harvest, grain yield was assessed through sample crop cuts. The transplanting times had significant effects on the grain yield. The June and early July transplanted crop gave significantly higher grain yield compared to the late July transplanted crop. With the use of younger seedlings in machine planted rice, transplanting rice as late as third week of July results in reduction of grain yield and therefore should be avoided.

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Keywords: Crop cut; grain yield; machine; transplanter; transplanting time; tray nursery.

1. Introduction

As rice commands number one position amongst cereals in Bhutan, certain strategies have been devised by the Department of Agriculture (DoA), Ministry of Agriculture and Forest for enhancing rice productivity and production in the country. One important strategy now and also to be pursued in the 11th FYP plan is mechanized rice farming. Although farm mechanization has been challenging, the identification and prioritization of areas for commercialized rice farming has been done and given priority. Of late, the DoA along with the Agriculture Machinery Centre (AMC) and other stakeholders has initiated rice commercialization program wherein farm mechanization is featured strongly and increased budgetary allocations have been ensured. The preliminary results from the mechanization interventions in rice farming have shown marked improvement in yield.

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Bhutan's rice farming is heavily challenged by rugged terrains and smaller window period for crop growth and development limiting to just a single cropping season. While information for traditional system of rice farming is available, there is a dearth of studies undertaken to study the different aspects of rice production under mechanized system of farming. Unlike the traditional system of rice production, which uses older seedlings, mechanized method uses younger seedlings of 20-25 days, necessitating change in timing for crop production. The use of younger seedlings in mechanized transplanting entails longer plant development period and it is imperative that there is a standardized calendar of operations for different agro-ecological regions of the country. Mechanized rice farming is just beginning to make foothold in Wangdue-Punakha valley. Timing for transplanting and other agronomic operations needs to be recommended for different regions. As rice production in Bhutan is being constrained by high cost of production and intensive labour use, mechanization could be promoted to economize rice production as there is drastic reduction in labour requirement (Yeshey, 2012). Grain yield of a crop, to a greater extent is determined by agronomic practices besides biotic and abiotic stresses. There is an increase in grain yield if management practices are improved (Shrestha, 2004; Dobermann and White, 1999; Fan et al., 2005). Thus, as part of agronomic intervention for mechanized rice farming in mid-altitude zones, studies to standardize management practices for mechanized rice farming including timing for nursery, transplanting, harvest, weeding and fertilizer application could be important as farmers switch on to mechanization from their traditional system of farming.

2. Materials and Method

The test variety for the experiment was IR-64 as it is the most popular improved rice variety which has performed well under different methods of production in mid-altitude areas. The experiment was conducted on farmer's field at Lobesa, Baap geog under Punakha Dzongkhag in 2012. The experiment was laid out as single plots with three random plots selected from within the single large stretch of rice field. Treatments consisted of three transplanting times: normal (23 June), delayed (7 July) and late (27 July).

Tray nursery technique was followed for raising seedlings wherein pre-germinated seeds were thickly broadcast at approximately 200-250 gm

per tray containing about 6-7 kg of sieved soil (sieved in 0.5 mm mesh) as growth media. After seeding, the seeds were covered by the same soil up to about 0.5 cm, leveled with a wooden scale and the base of the trays immersed in water to hydrate or saturate the entire soil. The trays were then lifted carefully and staked until the seeds germinated. The trays are then laid out in lines inside the ploy house and kept moist. Care was taken not to stagnate the water over the rim of the tray and monitoring was done at regular interval. A night before transplanting, the nursery trays are taken out for ease of separation of seedlings from the clump during transplanting. The 21 day old seedlings were transplanted using the transplanting machines at a distance of 20 x 20 cm. This way, an acre of land requires 80 trays of seedlings to be transplanted in 3-4 hour depending upon the terrace type and skill of operators. Cultural operations such as weeding, irrigation and plant nutrient applications were done similar to the normal crop and the crop was harvested at 85% maturity. Crop cuts from 6 m^2 were done to measure grain yield at harvest.

The data analysis was done using statistical tool R-Stat version R-2.15.1 and comparison among the treatment means was performed using Tukey HSD.

3. Result and discussion

3.1 Grain yield

The grain yield as assessed through the sample crop cut conducted at 85% crop maturity showed that there was a significant effect of transplanting time on the grain yield at Lobesa which corresponds to the mid-altitude rice zones of Bhutan. The grain yields among the three transplanting times were highly significant (Table 1). Higher grain yield was recorded from plots planted on 23 June and 7 July compared to late planting on 27 July. The late July transplanted plot gave the lowest grain yield of 2 ton/acre whereas the grain yield from the two early planted plots gave 3.23 t/acre and 2.36 t/acre grain yields, respectively (Table 2). The June planted crop produced the maximum grain yield which was 26% higher from late July planting.

Table 1. ANOVA of grain yield compared between three treatments.

Source of variation	DF	Sum of squares	Mean squares	F value	*P*
Treatment	2	2.3944	1.1972	11.06	0.0097**
Residual	6	0.6495	0.1082		

***: significant at 1% confidence level.*

Table 2. Mean grain yield (t/acre) between three treatments.

Treatment	Grain Yield (ton/acre)
Late June	3.23a
Early July	2.36bc
Late July	2cd

4. Discussion

Effects of season and timing of transplantation have always been an important consideration for rice crop agronomists. Seasonality of crops has greater bearings on the grain yield and the crop growing period is often determined by the timing of planting and sowing dates. Rice planted in June has longer and better growing period whereas those planted as late as third week of July extends its growing period to cooler October, thus markedly affecting grain filling. The late planted crop also does not get adequate time for completion of vegetative growth phase, particularly if young seedlings are used. That is why the grain yield was significantly be low in the late transplanted rice as compared to those transplanted early. In machine transplanted rice, the seedlings were just 21 days old implying that the plants required longer period for completing growth and development. Late planting is said to impose shorter cropping time leading to negative effects on the plant performance. In temperate regions, there is a delayed flowering and increased growth duration when rice plants are grown from low temperature zones (De Datta, 1981). The length of ripening of rice is highly affected by temperature and ranges from 30 days in tropics to 65 days in cool temperate regions (Yochida, 1994). Therefore, this experiment showed that for mechanized rice farming, nursery will have to be done earlier and transplantating must be completed in the first half of July.

The time of planting which affected grain yield was also to a greater extent affected by the two methods of planting, mechanized and

manual. Delayed planting did not have much adverse effect on grain yield when transplanted manually as the seedlings were old. But the effect was large in machine transplanted plots which could be attributed to use of young seedlings. This indicated that seedling age and timing of the planting operations will have to be considered to get good crop yield. However, the experiment showed that mechanized transplanting which used younger seedlings gave slightly higher yield compared to manual planting which used older seedlings, if transplanting time is early or normal.

Researchers have proven that use of younger seedlings preserved potential in plants to tiller more and attribute to enhanced yield capacity. Experiments involving System of Rice Intensification (SRI) techniques showed that use of younger seedlings resulted in enhanced growth and development contributing to increased yield (Stoop et al., 2005; Uphoff, 2004). The grain yield is significantly higher in early transplanted seedlings irrespective of the methods used for transplanting suggesting that delayed planting in general should be discouraged. With the current drive to mechanize rice farming, it is imperative that suitable planting times are recommended for farmers of all the regions.

5. Conclusion

The current experiment showed that there is a marked effect of transplanting time on the grain yield of machine transplanted rice in Wangdue-Punakha valley which corresponds to mid-altitude regions of the country. It is imperative that seedling age and nursery timing for mechanized rice farming in the country are studied and recommended. Traditionally, rice is transplanted from May-July in Wangdue-Punkha valley but for mechanized farming, delay in transplanting could result in reduced grain yield as the growth period of plants extends into the colder months of October and November. In such a situation there is negative effect on grain filling leading to reduced yield. Transplanting rice as late as the last week of July in mid-altitude regions for mechanized transplanting should be avoided. Therefore, mechanized transplanting is not recommended under delayed planting situations and for rainfed areas. Another important point to be concluded from this experiment was that rice yields are higher with the use of younger seedlings irrespective of transplanting method.

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Effect of Nitrogen on yield and its components in spring wheat in Bhutan

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Abstract

Five levels of nitrogen treatments (T1 = 0-0-0, T2 = 50-40-30, T3 = 80-40-30, T4 = 100-40-30 and T5 = 120-40-30 N: P_2O_5: K_2O kg $ha^{-1,}$ respectively) were used to determine the yield and its components in wheat in a field study at RDC Bajo. The trial was set in a randomized complete block design with four replications. The study showed significant difference ($P < 0.05$) between the treatments in grain yield with 100 kg N ha^{-1} producing the maximum yield of 3.86 t ha^{-1}. The other agronomic traits were also influenced by higher nitrogen rates with exception of kernel weight. The study suggests the recommendation of 100 kg N ha^{-1} for optimum production in mid-altitude areas.

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Keywords: Nitrogen treatments; randomized complete black design; wheat; grain yield

1. Introduction

Wheat (*Triticum aestivum* L.) is a secondary cereal in Bhutan as cultivated area is still marginal compared to other major cereals, maize (*Zea mays* L.) and rice (*Oryza sativa* L.). The RNR statistics of 2010 indicated that wheat is grown over an area of 2225 ha against 24,590 ha of maize and 22,550 ha of rice, producing about 4873 tons (DoA, 2011). The Policy and Planning Division (2011) estimated that wheat along with other cereals namely barley (*Hordeum vulgare* L.), millets and buckwheat (*Fagopyrum* sp.) contribute less than 10% to the national food basket. The national wheat productivity of 2.1 t ha^{-1} (DoA, 2011) is much less than the neighboring countries of 2.7 t ha^{-1} in India (Ortiz-Ferrara et al., 2007) and 2.7 t ha^{-1} in Nepal (Adhikari et al., 1999). China has a higher average yield of 4.4 t ha^{-1} (Wang et al., 2009), which could be due to more favorable environmental conditions or intense management or both.

The increase in productivity could be realized through breeding new improved cultivars or improving crop husbandry practices or both. The

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usage of chemical fertilizers as a source of nutrient would play a crucial role as a component of crop management practice. Indeed publications are abundant that demonstrate the improvement of crop production through application of inorganic fertilizers (Yadav et al., 1998; Fan et al., 2005). Nitrogen in particular is inevitable in increasing the vegetative growth, water use, partitioning of dry matter and maintaining grain protein levels (McDonald, 1992). The objective of this study was to determine the economic rate of nitrogen for optimum grain yield production.

2. Materials and Method

The study was conducted at Bajo research station at an elevation of 1250 m during the 2011-2012 cropping season. The soil was characterized as clayey loam (NSC, 2009). The chemical characteristics and temperatures of the site are summarized in Table 1 and Figure 1 , respectively. The trial was laid out in Randomized Complete Block design with four replications. The plot size was 9 m x 3 m and spacing of 20 cm between rows was maintained to facilitate weeding and other intercultural operations. The seed rate used was 120 kg ha^{-1}.

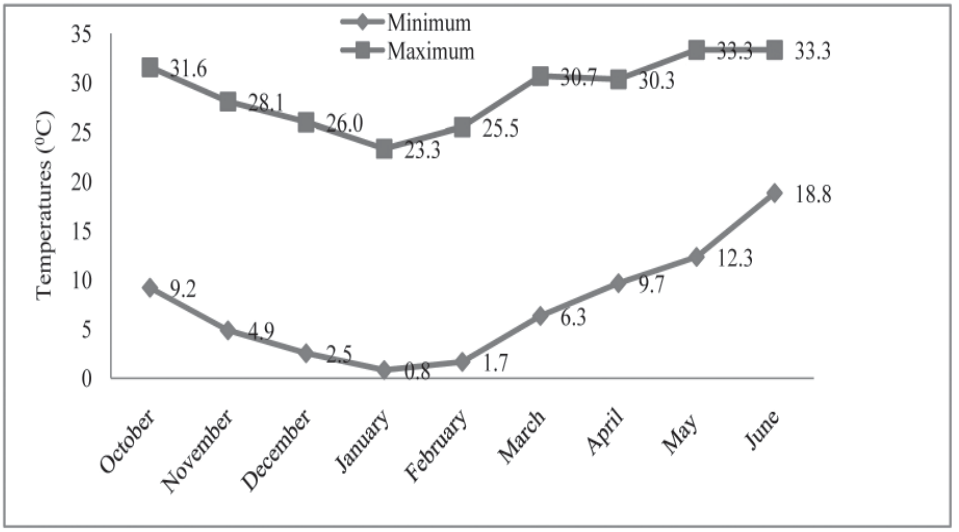
The treatment consisted of T1 = 0-0-0, T2 = 50-40-30, T3 = 80-40-30, T4 = 100-40-30 and T5 = 120-40-30 N: P_2O_5: K_2O kg ha^{-1} respectively. 50% of N and full dose of P and K were applied as basal during final land preparation, while the remaining N was applied at maximum tillering stage, a month and half after sowing. The crop received four irrigations during its entire crop period, and weeding was done when required. Among the weeds, little canary grass (*Phalaris minor)* was the most dominant and problematic weed. At maturity, different agronomic traits such as plant height, spike length, number of kernels per spike, 1000 kernel weight and grain yield were gathered. The grain yield was estimated from 6 m^2 crop cut area, and an improved variety, Sonalika was used for the study. Crop was planted in November 2011 and harvested in May 2012. The preceding crop in the trial site was rice.

The data were analyzed by Analysis of Variance at 5% significant level by using data analysis software R (R Development Core Team 2010). The difference between means was separated by 95% confidence interval.

Table 1. Soil chemical properties of the site

pH	Total N (%)	Bray-P (mg kg^{-1})	Available K (mg kg^{-1})	Total C (%)
`	0.10	5.04	55.87	1.2

Figure 1. Temperatures at the test location during the season 2011-2012



Result

Addition of nitrogen had an effect with statistics showing a significant difference ($P < 0.05$) in all the measured agronomic parameters except 1000 kernel weight ($P > 0.05$) (Table 2). As the nitrogen rate increased, there was a linear increase in most of the agronomic traits. The agronomic traits, however, plateaued at 100 kg N ha^{-1} indicating that this rate would be economical for optimum production. There was a significant difference ($P < 0.05$) in grain yield (Figure 2) and same trend with optimum nitrogen rate could be observed as with other traits.

Table 2. Agronomic traits at different nitrogen rates

Treatment (N Kg ha^{-1})	Plant height (cm)	Spike length (cm)	1000 kernel weight (g)	No of kernels spike $^{-1}$
T1 = 0	73 ^{c}	6 ^{a}	56 ^{a}	31 ^{a}
T2 = 50	84 ^{a}	8 ^{ab}	59 ^{a}	39 ^{ab}
T3 = 80	96 ^{b}	10 ^{b}	57 ^{a}	44 ^{ab}
T4 = 100	96 ^{b}	10 ^{b}	55 ^{a}	50 ^{b}
T5 = 120	96 ^{b}	10 ^{b}	53 ^{a}	48 ^{b}
P	<0.05	<0.05	0.23	<0.05

Means followed by same letters within the columns are not significantly different at $P \leq 0.05$

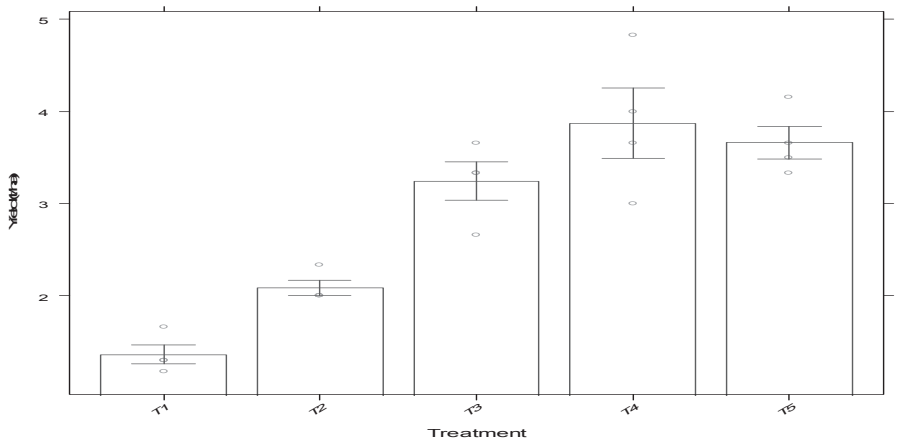


Figure 2. Wheat grain yield at varying nitrogen treatments. Vertical segments are the standard error of means.

3. Discussion

In Bhutan, there is a wide gap in grain yield between the research stations and farmers' fields, considering the maximum yield of 3.86 t ha^{-1} from 100 kg N ha^{-1} of current study, and existing national productivity of 2.1 t ha^{-1}. While the role of other nutrients can't be ruled out completely, there exists an opportunity to narrow this gap if crop is nourished adequately with chemical fertilizers particularly nitrogen. However, wheat farmers in Bhutan pay little attention to nutrient management as wheat is a secondary cereal, coupled by issues of fertilizers availability and affordability due to import from India. The same challenge of insufficient

nitrogen fertilization by the farmers leading to low productivity was reported in Nepal (Adhikari et al., 1999).

This study demonstrated the significant increase in most of the agronomic traits with increase in nitrogen level, agreeing with the previous findings of Adhikari et al., (1999) and Fois et al., (2009). However, the economic level of nitrogen at 100 kg N ha^{-1} in the current work contradicted with the observations of Maqsood et al., (1999) who reported significant yield and yield components increase at more than 120 kg N ha^{-1}. The complete attributing circumstances to this difference are not understood, but nitrogen use efficiency is also determined by other nutrients (e.g., sulphur availability influence nitrogen uptake as reported by Salvagiotti et al., 2009).

The reductions in kernel weight and number of kernels per spike at higher rate of nitrogen (e.g., 100-150 kg N ha^{-1}) are well documented (McDonald, 1992). We also observed similar trend as nitrogen rate passes 100 kg N ha^{-1}. It was suggested that increased remobilized dry matter brought by higher nitrogen rate made insignificant contribution to kernel growth (McDonald, 1992). The higher nitrogen rate could also accelerate the shortening of grain filling duration leading to reduced kernel weight (Fois et al., 2009).

The issues and challenges in managing the productivity under rice-wheat system, one of most dominant systems in South and East Asia, has been well illustrated by Timsina and Connor (2001). In Bhutan too, this system is perceived as one of the potential areas for improving wheat production owing to congenial environmental conditions. Thus, nutrient management will play a major role in sustaining the yields of both rice and wheat, and minimizing the ill effects of crop intensification.

4. Conclusion

The prime objective of the study was to determine the most economical and appropriate level of nitrogen for the farmers in the mid altitudes where rice is substantially followed by wheat as a rice-wheat farming system. Given the representativeness of the test location, it may be concluded that wheat farmers could be advised on the usage of recommended nitrogen, 100 kg N ha^{-1} to optimize the production in rice-wheat system.

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Performance evaluation of improved rice varieties at RDC Bajo

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Abstract

A rice varietal performance trial was conducted at RDC Bajo in 2011-2012 involving nine improved varieties including Bajo Kaap2 and standard check. The varieties were the elite selections from a total of seventy eight entries introduced from the International Rice Research Institute in the Philippines and evaluated from 2008 -2011. The entries were mainly evaluated for grain yield, days to flowering, plant height, resistance to diseases and pests, and number of productive tillers. Randomized Complete Block Design was followed and a standard management system was applied. The crop performance was assessed and three entries viz. BP-176, IR-28 and PSBRC-60 were selected as the best performers for further testing. BP-176 produced a grain yield of 4.33 t ha^{-1}, while IR-28 and PSBRC-60 gave 3.90 t ha^{-1} and 3.58 t ha^{-1}, respectively. Based on the on-station evaluation and the results of preceding experiments (2008-2011), the top performing entries have been earmarked for testing in the farmer's field in Wangdue-Punakha valley.

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Key words: Entries, Germplasm, Crop performance, Evaluation, Multi-location, Grain yield

1. Introduction

Rice is the most important food crop of Bhutan and research and development in rice is being given high priority by the government. In the last couple of decades, the Regional Research and Development Centres, under the Ministry of agriculture and Forests, have made tremendous strides in improving the national rice productivity from 1.53 t ha^{-1} in 1989 to 3.18t ha^{-1} in 2010 (Ghimiray, 2012). The major breakthrough in rice development came with development and release of high yielding varieties. Most of these released varieties are resistant to major diseases like rice blast and other biotic and abiotic stresses. Currently research works are underway to screen and release multi-stress resistant varieties in the wake of impending

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drought and climate change affecting crop production in the country. With mounting importation of rice and challenges posed by the vagaries of climate change and reduction of cultivable area for domestic production, research and development in rice becomes indispensible for food security and sovereignty of the country. The RDCs have been introducing and testing the performance of new materials through adaptive trials before releasing for general cultivation. Currently, Bhutan has released 23 improved varieties for the whole country which is inadequate given the diversity of growing environments. One of the ways of increasing grain productivity is through use of high yielding varieties together with improved management practices (Shrestha, 2004; Dobermann and White, 1999; Fan et al., 2005). Efforts are underway to replace low yielding varieties by improved ones to reach a national average target of 3.75 t ha^{-1} at the end of 11 FYP. Currently, the rice variety adoption rate stands at 42% (Ghimiray, 2012). The present study has an important objective to evaluate the performance of germplam received from International Rice Research Institute in the Philippines at the research station level.

2. Materials and Method

The experiment was conducted in the main rice season (June to October) at RDC Bajo and nine superior entries (including Bajo Kaap 2 as local check) selected from the previous year's experiment were used as the test material in 2011-2012. The experiment was laid out in RCBD with 3 replications. Thirty five day old seedlings grown using semi-dry bed method were transplanted on $10m^2$ plots at a spacing of 20 x 20cm. Chemical fertilizer was applied at the rate of 70:40:40 NPK kg ha^{-1} with half N and full dose of PK as basal dose and half N as top dress at panicle initiation. Butachlor 5G was applied at the rate of 1.5 kg a.i ha^{-1} after two to three days of transplanting to control the weeds. At a later stage hand weeding was done as and when required. Irrigation was given depending on the requirement and timely monitoring of pest and diseases was carried out. The basic agronomic traits such as plant height, days to 50% flowering, number of productive tillers per hill, and grain yield were measured. Grain yield was measured at 85% maturity from an area of 6 m^2 and grain moisture adjusted to 14%. The crop performance parameter such as number of productive tiller was counted at harvest and and averaged from 10 hills per plot. Panicles bearing five or more spikelets were counted as productive tillers. Plant height was taken at heading stage from 10 hills in each of the

plots. The data was analyzed using IBM SPSS statistical software version 20, and comparisons among the means were done using LSD at 5% level of significance.

3. Result and Discussion

3.1 Plant height

Measurement of plant height was done at crop heading stage when the flag leaves were fully expanded. The different entries used in the experiment showed significant variation in plant height. Average plant height among the entries varied between 95 cm to 166 cm (Figure 1). For rice breeders, plant height is an important criterion and grain yield and plant heights were correlated in the development of new plant types or the ideotypes (Yang et al., 2004). Short and sturdy plants are considered best for carrying heavier panicles but under the Bhutanese context, a medium plant height of about 105-115cm would be ideal as there is balance of straw as well as the grain yield. The entries with ideal plant height were PSBRC 60, BP-176, and IR-28 whose plant height ranged between 106 to 114 cm. Based on the plant height and other favorable plant characteristics studied in this experiment, the above three entries are suitable for Bhutan. The taller ones are outliers which are considered too tall and do not meet the objective of the evaluation.

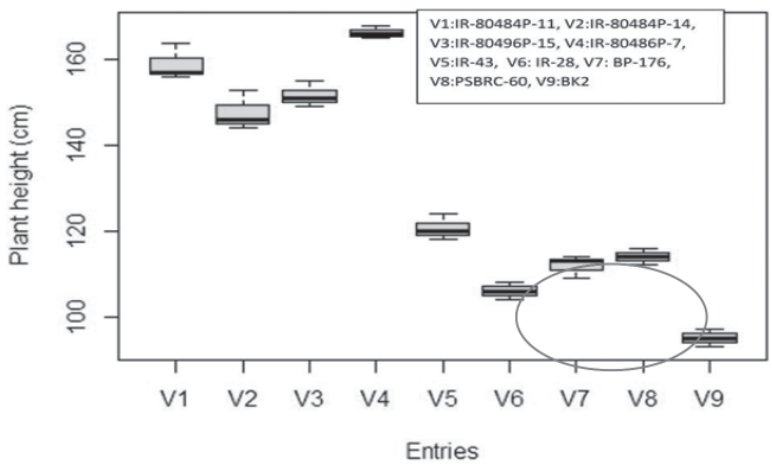

Figure 1. Box plot of plant height variation among the 9 test varieties

3.2 Days to 50% flowering

Days to 50% flowering showed significant variation among the test entries (Table 1). Entries such as IR-80486-P7, IR-80496-P15 and IR-80484-P11 took over 130 days to flower whereas IR-28, IR-43, BP-176 and PSB RC 60 took just about 114 days. The entries which took less number of days to flower fall more or less within the same flowering range as the standard check (BK2). These varieties should be acceptable to the Bhutanese farmers if their grain yield is good. With untimely rainfall and unpredictable weather, shorter duration varieties are ideal for Bhutanese farmers. The target of earliness in varieties is for avoidance of unfavorable conditions and provide window of opportunities (IRRI, 1994). Earlier the flowering earlier will be the time to harvest.

3.3 No of productive tiller/hill

The entries showed significant difference in number of productive tillers per hill. The highest and lowest number of productive tillers per hill recorded in this experiment was 20 and 12 which corresponded to IR-28 and IR-80496P-15 respectively (Table 1). In general, there was not much variation in productive tillers among the entries and the numbers in the current experiment are a little higher than normally seen in the farmer's field. This production of higher number of tillers at Bajo farm could be attributed to improved management practices. Productive tillers are one of the main yield components in rice which has greater bearing on the grain yield. Plants producing higher number of tillers have higher yield potential in rice (Yan et al., 2010).

3.4 Grain yield

The final grain yield adjusted to 14% moisture level showed significant variations among the test entries (Table 1). BP-176 was the top yielder with grain yield of 4.33 t ha^{-1}. Other entries which recorded high grain yield were R-28 (3.90 t ha-1), IR-43 (3.58 t ha-1) and PSBRC-60 (3.54 t ha-1). Grain yield produced by these entries were statistically same with that of the local check (BK2) which gave 3.91 tons ha^{-1}. Entries such as IR-80484-P11, IR-80484-P14, IR-80486-P17 and IR-80486-P7 recorded low grain yield which ranged between 2.20 - 2.50 t ha^{-1}. This was significantly lower compared to the grain yield of the control, BK2. The

overall grain yield in the current experiment was a little lower compared to the results of the past experiments from 2008-2010 (Table 2). However, the entries such as BP-176, IR-28 and PSBRC-60 have performed consistently well (RNR RDC Bajo, 2008; RNRRDC Bajo, 2009; RNR RDC Bajo 2010). Improved varieties, if backed up by good crop management with better fertilization regime will give stable yield (Saito et al., 2006).

Table 1. Basic agronomic traits of nine elite entries evaluated in 2011

Variety	Days to 50% flowering*	No of productive tillers/ hill*	Grain yield (t ha^{-1})*
IR80484 p-11	137g	14ab	2.30 a
IR80484 P-14	128e	12a	2.20 a
IR80496 P-15	136f	12a	2.56 a
IR-80486 P-7	140h	19cde	2.28 a
IR-28	112a	20cde	3.90 bc
BP-176	114cd	15abc	4.33 cd
IR-43	114cd	13ab	3.58 b
PSBRC 60	114bc	19cd	3.54 b
BK2	113ab	16bc	3.91 bc

** -Significant at 5% level Column means indicated by the same letter(s) are not significant at 5% LSD level.*

Table 2. Performance of three best promising entries evaluated at RDC Bajo from 2008-2011)

Variety	Days to 50% flowering	No of tillers $hill^{-1}$	Plant height (cm)	Yield t ha^{-1}	Year
IR28	127	16.00	96	4.91	2008
IR28	131	15.00	110	7.92	2009
IR28	130	12.00	107	4.7	2010
IR28	112	20.00	106	3.9	2011
BP176	133	14.00	116	4.91	2008
BP176	125	14.00	120	10.67	2009
BP176	131	12.00	116	5.8	2010
BP176	114	15.67	112	4.33	2011
PSBRC60	132	14.00	101	4.05	2008
PSBRC60	133	14.00	120	10.78	2009
PSBRC60	124	13.00	121	5.7	2010
PSBRC60	114	19.50	114	3.54	2011

4. Conclusion

From this experiment, the three entries, BP-176, IR-28 and PSBRC-60 were selected for further testing in the farmers' field. A series of initial evaluation trials at Bajo research station have proven that these three entries have performed consistently well. Four year's average grain yield of these three entries stood at 5.3 t ha^{-1} for IR-28, 6.4 t ha^{-1} for BP-176 and 5.8 t ha^{-1} for PSBRC-60. These elite germplasm were screened from as many as seventy eight entries introduced in 2008. The current experiment culminates RDC Bajo's on-station performance trials involving 78 entries resulting in selection of the three entries for testing in the farmers' field.

Acknowledgement

The authors would like to sincerely acknowledge the field workers (ESPs) of RDC Bajo for their punctuality and assistance during the conduct of this experiment. Gratitude is also extended to the Program Director and Rice Specialist for their guidance and all other research colleagues for their support.

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An assessment of inputs use in Potato production in Phobjikha and Gangtey

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Abstract

Wangduephodrang, Phobjikha and Gangtey are major potato producing areas. Because of the crop's high productivity, wide adaptation, and commercial value, it has provided significant income for the farmers. However, potato production in these areas did not come without a cost. Farmers apply higher rates of inputs on potato while yields are on the decline. This study therefore assessed input use in potato production. Household interviews were conducted in 153 households. Application dosage of metribuzin range between 2 – 3gm/litre water, glyphosate between 3.2 – 3.8 ml/litre water and mancozeb between 4 – 6 gm/litre water. According to NPPC, the recommended application dosage of metribuzin is 1 gm/litre of water, glyphosate is 2.5 ml/litre of water and mancozeb is 2 gm/litre of water. Commonly use inorganic fertilizers include Suphala, Urea and SSP. Of the total respondents, 15% practiced balanced fertilization, 30% applied Suphala and SSP, and 24% applied Suphala only. The average application rate practiced by majority is 95:70:45 NPK kg/acre while the recommended rate is 40:32:32 NPK kg/acre. Irrespective of inputs, application rates exceeded the recommended rates. It is not known whether it is the awareness and related factors, especially the knowledge regarding inputs and their associated benefits and risk, or lack of awareness about the recommended rates that led farmers to using higher rates.

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Keywords: Potato; production; income; inputs; application

1. Introduction

Potato is grown widely in Bhutan from the wet-subtropical to cool temperate zones. It is one of the most important cash crops in Bhutan. It ranks first in terms of volume of agriculture trade and is placed second in terms of value of export (next to oranges). Potato is one crop that has transformed traditional subsistence farming practice to a market oriented production system. According to the RNR Statistics, the area under potato cultivation in these gewogs is increasing dramatically. In Gangtey geog, the

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area has increased from 288 acres in 2004 to 541 acres in 2010. Similarly in Phobjikha geog, the area has increased 445 acres in 2004 to 466 acres in 2010.

Most farmers located at mid and high elevations are dependent on potato production for a significant portion of their livelihood. Potato is produced by all kinds of farmers from small landholders to tenant and large farmers. It is grown by all types of farmers from high altitude yak herders to the farmers of the sub-tropics and consumed by almost all people from children to old and poor to rich. In Wangduephodrang Dzongkhag, Phobji and Gangtey gewogs are known for potato and are the largest potato producers. Because of the crop's high productivity, wide adaptation, nutritional attributes, and commercial value, improved market, potato has provided tremendous impact through income for farmers of these gewogs. Without potato many households would have to find off-farm work to generate income and/or migrate to urban centers. For them potato is at present the only economic cash crop available for both, local and export markets. They meet their demand of annual supply of rice, clothes and household needs using the cash earned from selling potatoes. The cash crop thus has one of the important influences on the socio-economic conditions of the farmers.

However like any other developmental venture, potato production in Phobji and Gangtey gewogs did not come without a cost. Farmers in both gewogs are believed to apply high amounts of inputs to boost potato production with apparently declining of potato yields. The RNR Statistics showed that potato yield is on the decline, especially in Phobjikha gewog. The productivity has declined from 10,606 kg/acre in 2004 to 3288 kg/acre in 2010. The similar trend is also observed in potato productivity in Gangtey. This declining in productivity must be the reason that has led farmers to apply higher doses of inorganic fertilizers, fungicides and herbicides with the belief that higher dose means more effective and higher production. The challenge is to maintain or improve soil fertility and to maintain or increase production economically while at the same time minimizing environmental impacts. This study is thus planned and carried out to confirm the general assumption about farmers applying higher doses of inorganic fertilizers, fungicides and herbicides than the recommended rates. The specific objectives are to identify the types, validate the time, rate and frequency of application of inputs, and see if there is any change in rate,

frequency of application and to document the reasons for change in rate and frequency over the years.

2. Materials and Method

2.1 Site Selection

Gangtey, and Phobjikha are the two main potato growing g*ewogs* in Wangduephodrang Dzongkhag, therefore both the g*ewogs* are selected for the study. To gather more representative information for the gewogs, all the chewogs/villages in both the gewogs are selected. From each selected c*hewog*, of the total households in the c*hewog*, 30 percent of the household are selected randomly for the interview. Therefore, a total of 83 households from Phobjikha *gewog* and 68 household from Gangtey *gewog* were interviewed.

2.2 Method of data collection

The formal household survey was carried out using pre-tested and structured survey questionnaires. The questionnaire consisted of both closed and open-ended questions and collected both qualitative and quantitative information from the representative farmers. The questions pertained to main topics: (i) types of inputs, (ii) rate, time and frequency of application, (iii) changes in rate, time and frequency of application and (iv)reasons for the change. The interviews were carried out at each respondent's homestead.

2.3 Data processing and analysis

Both quantitative and qualitative data generated from the field were analyzed using Microsoft Excel and Statistical Package for Social Science (SPSS) version 16. For qualitative data, non-parametric test, frequency distribution, and descriptive statistics were performed. Descriptive statistics were applied to calculate the frequency, percentages, minimum value, maximum value, mean, standard deviation and standard error of different numerical and categorical data.

3. Result and Discussion

3.1 Respondent information

A total of 153 farmers were interviewed (83 from Phobjikha and 68 from Gangtey). Of the total 153 respondents, majority (58%) of them was male and (42%) was female. Regarding the age composition of the respondents, majority of them were adult (86%), while 12% was old and only 2% was young. Irrespective of age and gender, the occupation of all respondents is farming.

3.2 Land-use type and land holding

The main land-use type in both the gewogs is dry land. Of the total, 153 respondents interviewed, majority of them (56%) have land holding between 1.1 to 3 acres while (36%) of them have land holding between less than 1to 1 acre. Only 8% of them have land holding higher than 3 acres. The maximum dry land holding among the respondents is 7 acres and the minimum is 0.25 acre. Respondents are categorized into three dryland holding groups, such as small dryland holding (<1 acre), medium dryland holding (1.1-3 acre) and large dry land holding (>3 acre). Findings showed that majority of the respondents fall under the medium land holding category.

3.3 Livestock type and purpose of rearing

Main livestock reared by the respondents are cattle, pig, poultry, sheep and few horses. The main purposes of keeping each livestock are tabulated below.

Table 1. Types of livestock and their purpose

Livestock type	Purpose of rearing
Cattle	Draught power, dairy products, manure, and meat
Pig	Meat and to sell in times of urgent money requirement
Poultry	Eggs
Sheep	Wool and meat
Horse	Transportation

In addition to the above mentioned purposes of rearing different livestock animals, most of the respondents also indicated the use of manure for various purposes. Among the livestock animals, the highest population reared by each respondent is the cattle followed by sheep and poultry. The maximum number of cattle reared by a household is 45 heads with average of 10 heads.

3.4 Main crops cultivated and their productivity

While the main crop of the gewogs is the potato, other crops like buckwheat, barley, turnip, radish, beans and wheat are also cultivated after or before potato by most of the respondents. Main crops grown and their average yields are provided in (Table 2).

Table 2. Main crops grown and their average yields

Crops	Yield (Kg/acre)
Potato	6716
Buckwheat	819
Turnip/radish	2789
Beans	813
Wheat	590
Barley	620

Among other crops grown by the respondents, turnip and radish are mainly for livestock feed during winter season, buckwheat, barley and wheat are for home consumption as well as for making alcohol and beans are for home consumption and for sale locally.

3.5 Cultivated area and production of potato

All the 153 respondents reported to be cultivating potato on varying area. The largest area under potato production by an individual household is 5 acres. On an average, every household grows potato on an area between 1.5 to 2 acres. Similarly, the highest potato yield reported is 10000 kg/ac and the minimum is 2400 kg/acre. The average potato yield of the two gewog is about 6716 kg/acre.

3.6 Potato yield trend

Of the total 153 respondents, majority (55%) reported declining potato yield, while (35%) of them feel that the yield is increasing. Only about (10%) thinks that the yield is constant (Figure 3).

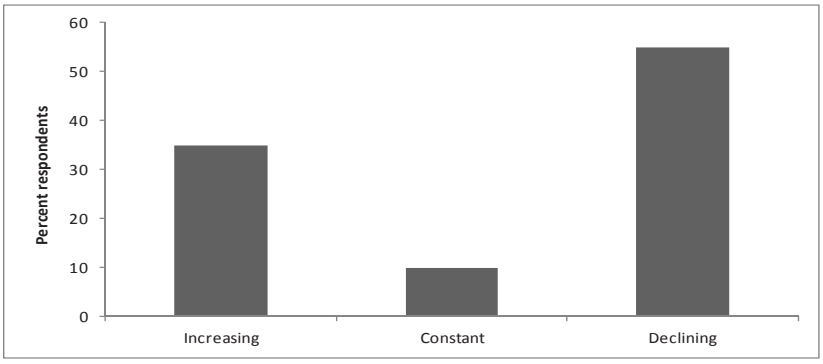

Figure 1. Respondents' perception of potato yield trend

Respondents' perceived reasons for potato yield declining are tabulated below. Declining soil fertility followed by potato blight are the main causes of declining potato yield. Among the four reported factors contributing toward potato yield declining, declining soil fertility stand out to be the most important one. This could be because of the fertilization practice (higher rate and imbalanced fertilization) that is common in the valley. The practice must have depleted certain nutrients, for instance K and other macro and micro nutrients which are applied in limited quantity or not at all. Similarly certain nutrient such as P must have build up from over fertilization.

Table 3. Reported reasons for potato yield declining

Reason	% Respondents
Declining soil fertility	45
Potato blight	27
Wild animal damage	20
Insect pest damage	8

Similarly reasons for increasing potato yield are provided in (Table 4). Respondents mostly attributed this to increased use of soil nutrient inputs such as inorganic fertilizers.

Table 4. Reported reasons for potato yield increasing

Reason	% Respondents
More inorganic fertilizer application	38
More farmyard manure application	31
Soil is fertile	25
Cultivated high yielding variety	6

Most respondents are of the view that their potato yield is increasing because they have applied more inorganic fertilizer. Another 31% think that increasing in potato yield is mainly due to application of more farmyard manure. More application of farmyard manure will certainly improve potato yield, but more application of inorganic fertilizer may not necessarily be the reason for increased in potato yield. While high inputs are required to achieve the potential yield and replace the nutrient removed, the average quantities of inorganic fertilizers used are still higher than the recommended rates. This is confirmed by a study done by RDC Bajo in 2004, through mass soil sample analysis, which showed that there is already Phosphorus build up in the soils of Phobjikha valley. This shows that the inorganic fertilizer application rate is already higher than potato crop requirement which has lead to excess nutrient build-ups in the soil. Agriculture is listed as a major non-point source contributing to the water-quality impairment problems in many countries. Runoff nutrient concentrations generally increase as their availabilities in the soil increase. Thus, maintaining high potato yields with a minimum loss of nutrients to the environment will be a significant challenge in Phobjikha and Gangtey gewogs with the present trend of inorganic fertilizer application practice followed by the farmers in the valley.

3.7 Commonly cultivated potato variety

Among the two potato varieties (Yusikaap/Kurfu Toyti and Desiree) available in the valley, the commonly grown variety is the Desiree (Red variety). About 103 respondents reported to cultivate Desiree, 47 mentioned growing both varieties and only 3 grow either Yusikaap or Kurfu Joyti variety. Reasons for cultivating different potato varieties are tabulated below. Among four important criteria for selecting a potato variety to be

cultivated, selling price and eating quality (taste) are the two most important criteria mentioned my most respondents.

Table 5. Reasons for cultivating potato variety Desiree

Reasons	% Respondents
Fetches higher price	46
Good taste	32
Gives higher yield	12
Higher resistant to pest disease incidence	10

3.8 Insect pest Management

Although potato production in other parts of the country is often reported as severely affected by pests including the invasive potato tuber moth, leaf miner fly, native white grubs, cutworms, leafhoppers and aphids, the application of insecticides to control/manage insects damages in potato in Phobji and Gangtey gewogs is negligible. Of the 153 respondents, only 3 farmers mentioned using Cypermethrin 10 EC for insect management. The minimum use of insecticide could be because of the lesser insect damage incidences occurred as both gewogs are located at higher altitude.

Rodents such as rats related problem in potato both in storage and in the field are mentioned by most of the respondents. However, only few respondents reported using Zinc Phosphide as control measure. Most farmers are aware of the health related hazardous from using Zinc Phosphide and are not using any rodenticide. These farmers control rodent by keeping traps and cats in the potato store houses. In the field they control through improving the field sanitation.

While potato is said to be susceptible to various fungal, viral and bacterial diseases, at the study sites, only late blight (*Phytophthora infestans*) is mentioned as the most important disease. All the 153 respondents reported that the disease appears almost every year and affect their potato crop significantly. The main control measure practiced by all the respondents is the use of fungicide. Mancozeb is the commonly used fungicide on potato in both the gewogs. About (82%) of the respondents mentioned applying Mencozeb on potato. The rest (18%) were not applying mainly because of inadequate labour for applying the fungicide. The other fungicide which is not use commonly but mentioned to have been in the

place before is Ridomil (Metalaxyl). Only few respondents reported applying this fungicide.

Percent respondents applying Mancozeb on potato is provided in (Figure 4). Percent of farmers using Mancozed has increased over the years. In 1980 there was only 1.3% farmer using Mancozeb which has increased to 82% in 2009. Mancozeb is used mainly for controlling potato blight. While the fungicide is the most commonly used by the respondents, there is some difference in time of application of the fungicide among the respondents. Most of the respondents (43%) mentioned applying Mancozeb on potato at vegetative development stage. About (34%) of the respondents reported to apply just before harvesting and another (23%) respondents mentioned applying before flowering stage.

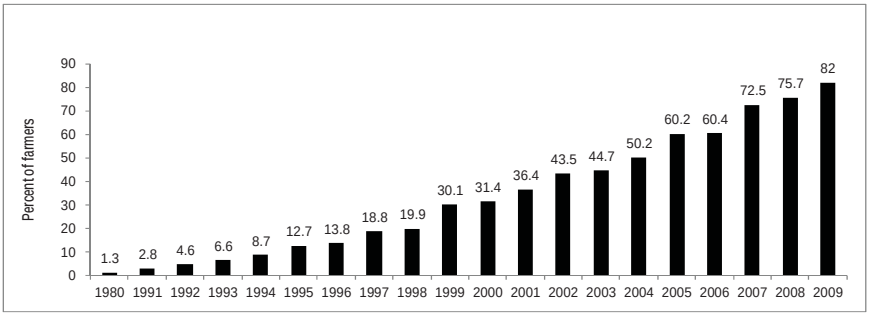

Figure 2. Percent farmer using Mancozeb over the years

The application dosage of the fungicide among the 153 respondents varies from respondent to respondent. The dosage ranges between 4 – 6 gm/litre water with most respondents falling within the higher range. According to National Plant Protection Centre (NPPC), the general recommended application dosage of the fungicide is 2gm/liter water. While the application dosage determined by the severity of the disease, stage of the crop and the application method (Blanket and selective), the survey results indicated that the fungicide application dosage of the respondents is higher than the recommended as perceived. Furthermore, the frequency of application of the fungicide differs among the respondents. While more than half of the respondents reported to apply only once, there are respondents who apply as many as three times during one crop season (Figure 5).

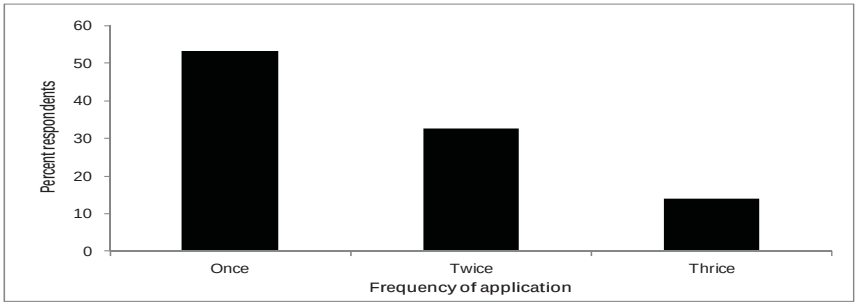

Figure 3. Frequency of Mancozeb application on potato

Whether respondents apply once or thrice, the main purpose of application is similar across all farmers. It is applied mainly for controlling potato late blight and its application dosage has been changing. The application dosage has increased as mentioned by (60%) respondents and the reason for increasing the application dosage is for controlling late blight effectively with the believe that higher dosage means more effective.

3.9 Weed Management

Like in other parts of the country, farmers of Phobjikha and Gangety spend considerable time on potato weed management. Labour requirement for weed management is often mentioned as a major production constraint. Consequently, majority (93%) of the respondents mentioned using herbicides for weed control and management in potato. The commonly applied herbicides in both the gewogs are Metribuzin 70 WP (Sencor) and Glyphosate 41 EC (Roundup). Percent respondents and the year farmers started applying Metribuzin is provided in (Figure 6).

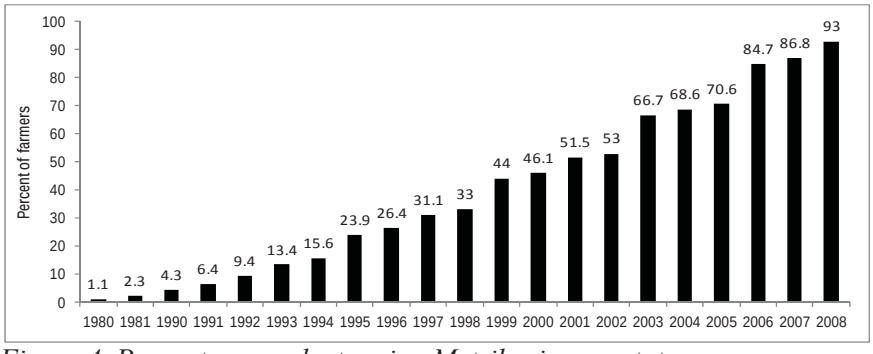

Figure 4. Percent respondents using Metribuzin on potato

Percent of respondents using Metribuzin on potato has been increasing over the years (Figure 6). This could be because of the high labour demanding nature of potato weeding coupled with household labour inadequacy. While there were only 1.1% respondents using herbicide on potato in 1980, the percent has increased to 93 in 2008.

The recommended application dosage of metribuzin according to NPPC is 1:1 (1 gm/litre of water). However at the study sites; the application dosage of Metribuzin on potato ranges between is 2 – 3 gm/litre water. Most respondents mentioned that weeds have developed resistance and if they do not apply more, it is not effective. Similar to the fungicide application dosage, respondents' application rate of Metribuzin is also found to be higher than the recommended dosage.

Time of application of Metribuzin on potato varies among the respondents. Majority (64.8%) reported to apply the herbicide during vegetative development stage and about (30.5%) mentioned applying after germination. Very few respondents reported to apply before plantation and before flowering. Frequency of application is only once in one crop season and it is same across all the respondents.

The other commonly used herbicide is Glyphosate. While Metribuzin is applied at earlier potato crop development stages to control weeds, Glyphosate is applied just before potato harvest to burn down the remaining potato above ground shoots and the weeds. This is practiced mainly because of labour shortage for hulm cutting before harvest. This makes the potato field clear and clean, making harvesting activity easier. Percent respondents and the years farmers started using Glyphosate is provided in (Figure 7).

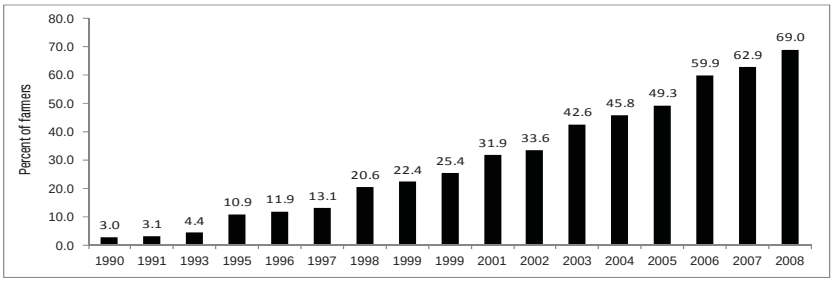

Figure 5. Percent respondents using Glyphosate on potato

Compared to Mancozeb and Metribuzin, Glyphosate application started only in 1990s (Figure 7). Frequency of application is just once, applied usually just before harvesting. According to most of the respondents (69%) in addition to the increasing number of farmers using the herbicide, the dosage of application is mentioned to have increased. The application dosage ranges between 3.2 - 3.8/litre water.

Irrespective of all inputs (fungicide and herbicide) the survey findings indicated that the application dosage of the respondents is higher than the recommended rate in both the gewogs. Furthermore, the application rate (dosage) is found to have increased in both gewogs. Besides the respondents' perception of higher dosage being more effective, the main cause of farmers applying higher dosage of herbicides and fungicide on potato is an area of concern. It is not known whether it is because of farmers being unaware of the recommended rates of the inputs.

3.10 Inorganic fertilization

Respondents from both the gewogs were well aware of the impact of nutrient management on potato yield. All respondents reported to apply considerable quantities of both organic and inorganic fertilizers. Amongst the inorganic fertilizers, the commonly applied fertilizers are Suphala, Single Super Phosphate (SSP) and Urea. While suphala and SSP are applied as basal dressing, urea is applied as top-dressing. The use of inorganic fertilizers is not new to the farmers of Phobji and Gangtey. Farmers in these gewogs have started using inorganic fertilizers on potato since 1980s and the number of farmers using fertilizers has been increasing since then (Figure 8).

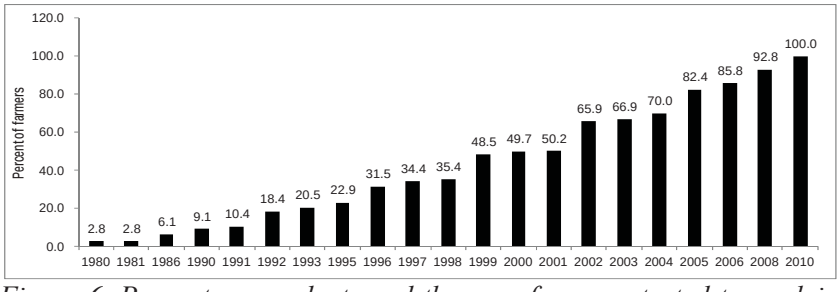

Figure 6. Percent respondents and the year farmers started to applying inorganic fertilizers

While potato like any other crop require a balanced fertilization for sustainable production, only (15%) of the respondents practiced balanced application. Of the total respondents, majority (30%) applied only Suphala and SSP, and about (24%) applied only Suphala (Figure 9). However, irrespective of the balanced and imbalanced fertilization, the application rate that respondents practiced in both the gewogs exceeded the recommended rate for both high resource and low resource potato growers of the Dzongkhag.

According to the fertilizer recommendation rate developed by the National Soil Service Centre (NSSC) Simtokha, the rates are 40:32:32 NPK kg/ac and 28:24:12 NPK kg/ac for high resource and low resource farmers respectively. According to the recommended rate the fertilizer requirements are 213:18 kg of Suphala:Urea for high resource farmers and 80:75:35 kg of Suphala:SSP:Urea for low resource farmers. However at the study sites, the average application rate of those respondents who practiced balanced fertilization is 95:70:45 NPK kg/Ac. The highest application rate mentioned was 205:138:90 NPK kg/Ac. Thus the findings indicated that respondents may not be deriving optimum yield and the economic benefits from their use of inorganic fertilizers mainly because of imbalance and higher rate of application. In addition, the practices may possibly entail potential long-term negative side-effect on the environment, especially for the water resources in the valley.

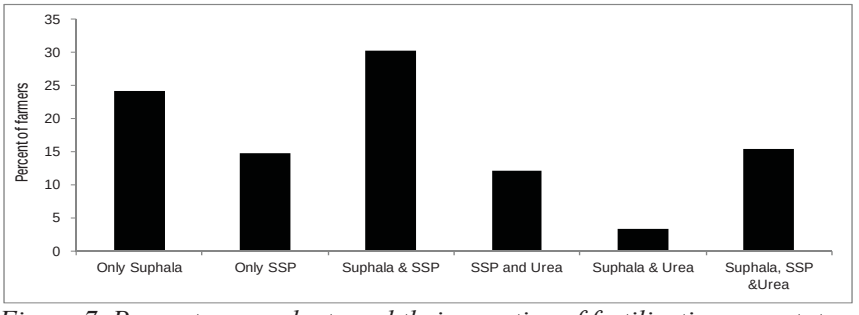

Figure 7. Percent respondents and their practice of fertilization on potato

The application rate goes same for the other combination of fertilization methods practiced by the respondents (Table 6).

Table 6: Respondents' fertilizer application rates

Fertilizer combinations	Maximum application rate (NPK kg/acre)	Minimum application rate (NPK kg/acre)
Suphala:SSP:Urea	205:138:90	30.5:15.5:7.5
Suphala:Urea	305:75:75	38:15:15
Suphala:SSP	75:170:75	10.5:18.5:10.5
SSP:Urea	345:96:0	23:9.6:0
Only Suphala	90:90:90	7.5:7.5:7.5
Only SSP	0:96:0	0:8:0

Percent respondents reporting the minimum application rate in both gewogs is very few. Majority of the respondents belong to the maximum and average application rate group. Therefore, the main fertilizer-use issue on potato is one of unbalanced fertilizer use with higher application rates than the recommendation.

3.11 Farmyard manure

In addition to the inorganic fertilizer application on potato, respondents from both the gewogs mentioned the application of farmyard manure. It is applied mainly during land preparation and incorporated during ploughing. The application rate ranges between 15.8 t/ac to 29 t/ha and the rate is said to have decreased over the years mainly because of the availability of inorganic fertilizers and inadequacy of farm labour.

4. Conclusion

Because of the crop's high productivity, wide adaptation, nutritional attributes, and market availability, potato has provided tremendous impact through income for farmers of these gewogs. For them potato is the only economic cash crop available for both, local and export markets to meet their demand of annual supply of rice, clothes and other household needs using the cash earned from selling potatoes.

Farmer in both the gewogs are found to be applying high amounts of chemical fertilizers, fungicides and herbicides to increase the production. While the application rates of inputs have increased, potato yield seem to have decreased as (55%) respondents reported declining potato yield. While in Gangtey both productivity and area under production has increased, in

Phobji both productivity and area under potato production has decreased. The productivity increase in Gangtey could be because of virgin land brought under potato production as they are believed to be more fertile than cultivated fields.

Potato production seems to be high inorganic input requiring system. According to the survey findings, the types of inputs used are herbicides (Metribuzin 70 WP and Glyphosate 41 EC), fungicide (Mancozeb 75 WP) and inorganic fertilizers (Urea, Suphala, and Single Super Phosphate). Of the total respondents (153) about (93%) reported to use herbicides for weed management. The commonly use herbicides are Metribuzin 70 WP and Glyphosate 41 EC. While Metribizin is applied to control weeds during potato growing stage, Glyphosate is applied just before potato harvest to burn down the remaining potato shoots and weeds. The application dosages are 2 – 3gm/litre water and 3.2 - 3.8ml/litre water mertibuzin and glyphosate respectively. The application dosage of both the herbicides exceeded the recommended rates and the main reason behind is the farmers' perception of higher dosage means more effective. It is not known if farmers' unawareness about the recommended dosages of the herbicides has let them to use higher rates. However irrespective of the herbicides, both number of farmers using the herbicides and the rate of application is reported to have increased over the years.

The commonly used fungicide for controlling potato late blight (*Phytophthora infestans)* is Mancozeb 75. While the fungicide is used by majority of the respondents, time of application differs amongst them. Most said to apply at potato vegetative development stage while others apply before flowering and before harvesting. The application dosage ranges between 4 – 6gm/litre water with most respondents falling under the higher dosage.

The use of inorganic fertilizers is rather not new to the farmers of Phobji and Gangtey and almost all the respondents use fertilizers on potato. Inorganic fertilizers include Suphala, Urea and SSP. Suphala and SSP are applied as basal dressing and urea as top-dressing. Of the total respondents, only (15%) practiced balanced fertilization, (30%) applied only Suphala and SSP, and about (24%) applied only Suphala. The application rate of those respondents who practiced balanced fertilization ranges between 95:70:40 - 205:138:90 NPK kg/Ac. However, whether balanced or imbalanced fertilization, the application rates that respondents practiced in both the

gewogs are found to be higher than the recommended rate for both high resource and low resource potato growers of the Dzongkhag. Irrespective of the types of inputs, the application rates are found to be higher than the recommended. It is not known whether it is the awareness aspects and related factors, especially the knowledge regarding inputs and their associated benefits and risk, or lack of awareness about the recommended rates that has let farmers to use higher rates and/or dosage of inputs on potato.

Potato cultivation is a high input system removing substantial quantities of soil nutrients. Consequently the system requires a sustainable nutrient management involving a set of management practices designed to conserve soil resources, to maintain or enhance productivity, and to help reduce growers' reliance on chemical fertilizers. Phobjikha being an important area firstly as the prime potato producing area and secondly the home of Black Necked Cranes in winter, it is very important for all relevant agencies to frame strategies that will improve soil fertility and to maintain or increase production while at the same time minimizing environmental impacts.

Acknowledgement

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Weeds of transplanted Rice in Western Bhutan

Sangay Dorji[6], Karma Lhamo, Karma Chophyll, Kezang Tobgye

Abstract

Weed survey in transplanted rice in western Bhutan for two rice seasons from June 2011 to October 2012 revealed 19 species of weeds infesting rice at Guma Geog and nine species each at Wangchang and Bjena Geogs. A perennial aquatic weed, Potamogeton distinctus was the most dominant weed species at Guma and Bjena Geogs while Blyxa aubertii was dominant at Wangchang Geog. The major weeds in western Bhutan, according to SDR are P. distinctus, B. aubertii, Schoenoplectus juncoides, Monochoria vaginalis, Paspalum distichum, Alternanthera sissilis, Cyperus difformis, Echinochloa sp., Fimbristylis littoralis, Commelina diffusa, Acmella uliginosa. The minor ones are Cyperus iria, Rotala densiflora, Bidens tripartita, Ischaemum rugosum, Arthraxon quartinianus, Cyperus rotundus, Fimbristylis aestivalis and Cynodon dactylon. Broadleaf (SDR=73) weeds were dominant among weed types followed by sedges (SDR=20) and grasses (SDR=7). I. rugosum is reported as one of the major weeds in Guma Geog. An aquatic weed, B. aubertii is emerging as a problem in areas where P. distinctus is controlled through hand weeding.

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Keywords: Potamogeton distinctus; *Blyxa aubertii*; Summed-dominance ratio; Weed composition; Butachlor; Transplanted rice.

1. Introduction

As in many countries in Asia, rice is a major cereal crop grown and the preferred diet of the Bhutanese. In 2010, area under rice production was 56, 375 acre with total production of 71, 637 tons(DoA, 2010). The national average yield stands at 3.18 t/ha compared to world's average of 4.4 t/ha. Bhutan's rice production meets only 48% of the home demand and rest are imported from India.

Weeds have been recognized as a major problem to man ever since humans started to cultivate crops. Worldwide, losses due to weeds have been estimated at 10% annually (De Datta, 1980). Increased rice yields have been achieved in other countries by improving weed management practices.

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For instance, yield gains of 200 to 600 kg ha^{-1} have been reported in Bangladesh through improved weed management practices (Riches et al., 2005). Bhutan can also benefit by improving weed management practices. However, proper identification of weeds is necessary before any intervention in weed management practices such as change in use of herbicide can be made. This work was, therefore, taken up to identify weeds present in transplanted rice system in western Bhutan and determine dominance of weed types with a goal to develop integrated weed management.

2. Materials and Method

The study was conducted in Paro, Punakha and Wangduephodrang Dzongkhag for two rice seasons from June 2011 to October 2012. Geogs were selected from each Dzongkhag based on the recommendation of the Dzongkhag Agriculture Officer. Wangchang Geog was selected from Paro Dzongkhag, Guma from Punakha Dzongkhag and Bjena from Wangduephodrang Dzongkhag (Table 1).

Table 1. Site location, elevation, rice area and production

Dzongkhag	Sampling site	Location	Elevation (m)	Rice area (ac)	Production (MT)
Paro	Wangchang	27.43°N, 89.42°E	2534	6784	12403
Punakha	Guma	27.58°N, 89.86°E	1350	6522	12425
W/phodrang	Bjena	27.47°N, 89.90°E	1368	5237	7645

A total of ten farmers were selected from each Geog who owned land not less than 0.50 acre. From each farmer's field, 10 samples were taken using a quadrant measuring 1m x 1m. During the second season, only five farmers were selected and only two samples were taken from each farmer due to resource and time constraints.

Samples were taken at 25-30 days after transplanting (DAT), 40-45 DAT and 70-80 DAT in a season. Weeds captured within the quadrants were carefully uprooted and washed free of soil and plant debris. They were then sorted by species, identified and counted. Data recorded included weed type, species, count (except *Potamogeton distinctus*), dry weight, relative

density (RD), relative dry weight (RDW) and summed-dominance ratio (SDR). For dry weight measurements, weeds were dried at 70°C for 48 hr using a hot-air oven. The SDR was computed using the equations (Janiya and Moody, 1989), SDR = (RD + RDW)/2, where, RD = (Density of a species/total density of all the species)/100; RDW = (Dry weight of a species/Total dry weight of all the species)/100. Relative contribution of broadleaf, sedges and grasses to weed community in terms of RD and RDW were also calculated.

3. Result and Discussion

3.1 Composition and weed dominance in Wangchang, Paro

Table 2. Weed species with relative density (RD), relative dry weight (RDW) and summed dominance ratio (SDR) at Wangchang*

Species	Family	Weed type	RD	RDW	SDR
Blyxa aubertii (L.C. Richard 1814)	Hydrocharitaceae	Broadleaf	57.09	46.80	51.95
Schoenoplectus juncoides (Roxb.) Palla	Cyperaceae	Sedge	20.56	10.08	15.32
Echinochloa sp.	Poaceae	Grass	2.53	21.34	11.94
Potamogeton distinctus A. Bennett**	Potamogetonaceae	Broadleaf	0.00	11.98	5.99
Cyperus difformis L.	Cyperaceae	Sedge	11.00	0.77	5.88
Monochoria vaginalis (Burm.f.) Presl.	Pontederiaceae	Broadleaf	6.98	3.95	5.47
Bidens tripartita L.	Compositae	Broadleaf	0.35	2.81	1.58
Paspalum distichum L.	Poaceae	Grass	0.22	1.79	1.00
Rotala densiflora (Roth.Ex R.&S.) Koehne	Lythraceae	Broadleaf	1.27	0.48	0.87

**Average of two seasons*
***Plant count of P. distinctus could not be taken due to difficulty in separating individual plants*

Nine weed species belonging to seven different families were identified in Wangchang Geog comprising five broadleaf, two sedges and two grasses (Table 2). *Blyxa aubertii* (L. C. Richard 1814), *Schoenoplectus*

juncoides (Roxb.) Palla and *Echinochloa* sp. existed in preponderance based on SDR; while other six were found to a lesser extent jointly contributing only 21% to the weed community. Broadleaf were dominant in the weed community with SDR 69 followed by sedges (SDR=17) and grasses (SDR=14). The contribution of broadleaf weeds to the weed community in terms of RD and RDW were 66% and 66%, respectively while sedges and grasses each shared 32% and 11%, respectively and 3% and 23%, respectively (Figure 1).

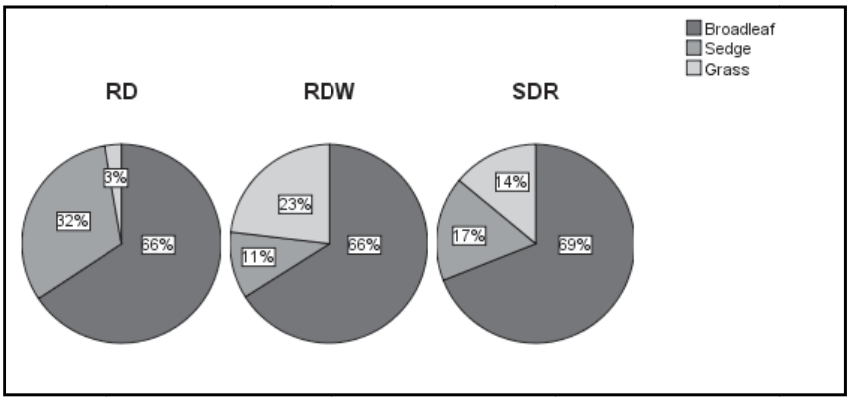

Figure 1. Relative density, relative dry weight and summed dominance ratio of different weed types at Wangchang

3.2 Composition and weed dominance in Guma, Punakha

Table 3. Weed species with relative density (RD), relative dry weight (RDW) and summed dominance ratio (SDR) at Guma*

Species	Family	Weed type	RD	RDW	SDR
Potamogeton distinctus A. Bennett**	Potamogetonaceae	Broadleaf	0.00	82.83	41.42
Blyxa aubertii (L.C. Richard 1814)	Hydrocharitaceae	Broadleaf	33.50	0.59	17.05
Alternanthera sissilis (L.) R.Br.Ex DC	Amaranthaceae	Broadleaf	17.14	2.96	10.05
Paspalum distichum L.	Poaceae	Grass	7.13	3.70	5.42

Schoenoplectus juncoides (Roxb.) Palla	Cyperaceae	Sedge	8.09	2.42	5.26
Fimbristylis littoralis Gaudichaud	Cyperaceae	Sedge	8.41	1.15	4.78
Acmella uliginosa (Schwartz) Cassini	Asteraceae	Broadleaf	6.95	2.38	4.66
Commelina diffusa Burm.f.	Commelinaceae	Broadleaf	9.00	0.09	4.55
Cyperus iria L.	Cyperaceae	Sedge	2.15	0.84	1.50
Echinochloa spp.	Poaceae	Grass	1.05	1.08	1.07
Cyperus difformis L.	Cyperaceae	Sedge	1.87	0.16	1.02
Ischaemum rugosum Salisb.	Poaceae	Grass	0.50	1.03	0.77
Arthraxon quartinianus (A.Rich.) Nash	Poaceae	Grass	1.10	0.02	0.56
Monochoria vaginalis (Burm.f.) Presl.	Pontederiaceae	Broadleaf	0.96	0.15	0.55
Bidens tripartita L.	Compositae	Broadleaf	0.64	0.13	0.38
Rotala densiflora (Roth.Ex R.&S.) Koehne	Lythraceae	Broadleaf	0.73	0.02	0.38
Fimbristylis aestivalis (Retzius) Vahl	Cyperaceae	Sedge	0.37	0.25	0.31
Cyperus rotundus L.	Cyperaceae	Grass	0.18	0.14	0.16
Cynodon dactylon (L.) Pers.	Poaceae	Grass	0.23	0.06	0.14

**Average of two seasons*

***Plant count of P. distinctus could not be taken due to difficulty in separating individual plants*

There were nineteen (19) weed species identified belonging to ten families comprising eight broadleaf, six sedges and five grasses (Table 3). *P. distinctus*, *B. aubertii*, *Alternanthera sissilis* (L.) R. Br. Ex DC and *P. distichum* existed in preponderance based on their SDR; while other fifteen were found to a lesser extent jointly contributing only 32% to the weed community. Maximum relative density was recorded with *B. aubertii* while maximum relative dry weight was recorded with *P. distinctus*. Broadleaf were dominant with highest SDR (79) followed by sedges (SDR = 13) and grasses (SDR = 8). Broadleaves contributed about 69% of the RD and 89% of the RDW followed by sedges (21% and 5%, respectively) and grasses (10% and 6%, respectively) (Figure 2).

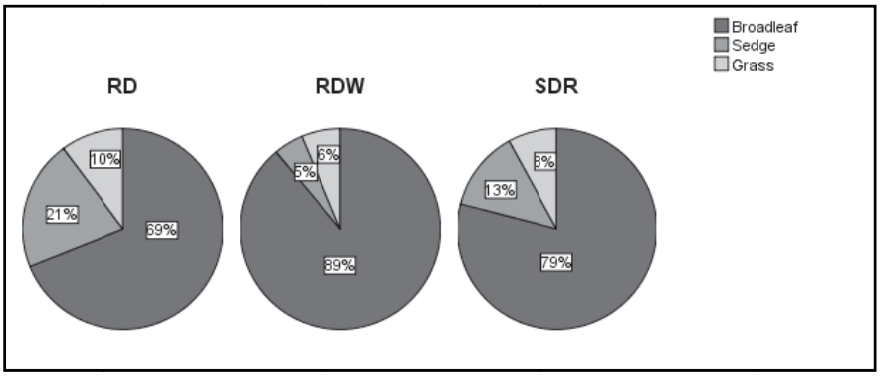

Figure 2. Relative density, relative dry weight and summed dominance ratio of different weed types at Guma

3.3 Composition and weed dominance in Bjena, Wangduephodrang

Table 4. Weed species with relative density (RD), relative dry weight (RDW) and summed dominance ratio (SDR) of Bjena*

Species	Family	Weed type	RD	RDW	SDR
Potamogeton distinctus A. Bennett **	Potamogetonaceae	Broadleaf	0.00	81.67	40.83
Schoenoplectus juncoides (Roxb.) Palla	Cyperaceae	Sedge	51.10	9.97	30.53
Monochoria vaginalis (Burm.f.) Presl.	Pontederiaceae	Broadleaf	29.56	2.35	15.95
Paspalum distichum L.	Poaceae	Grass	11.21	4.27	7.74

Echinochloa spp	Poaceae	Grass	1.43	1.32	1.37
Fimbristylis littoralis Gaudichaud	Cyperaceae	Sedge	2.42	0.03	1.22
Commelina diffusa Burm.f.	Commelinaceae	Broadleaf	1.98	0.29	1.14
Cyperus rotundus L.	Cyperaceae	Sedge	1.76	0.08	0.92
Arthraxon quartinianus (A.Rich.) Nash	Poaceae	Grass	0.55	0.03	0.29

**Average of two seasons*
***Plant count of P. distinctus could not be taken due to difficulty in separating individual plants*

Nine species of weeds belonging to five different families were identified in Bjena Geog, comprising three broadleaf, three sedges and three grasses (Table 4). *P. distinctus*, *S. juncoides*, *Monochoria vaginalis* (Burm. f.) C. Presl. And *P. distichum* existed in preponderance based on their SDR; while other five were found to a lesser degree jointly contributing only 5% to the weed community. Maximum relative density and relative dry weight were recorded with *S. juncoides* and *P. distichum*. Broadleaf were dominant with highest SDR (58) followed by sedges (SDR = 33) and grasses (SDR = 9). Sedges shared about 55% of the RD and 10% of the RDW while broadleaf shared 32% and 84%, respectively and grasses shared 13% and 6%, respectively (Figure 3).

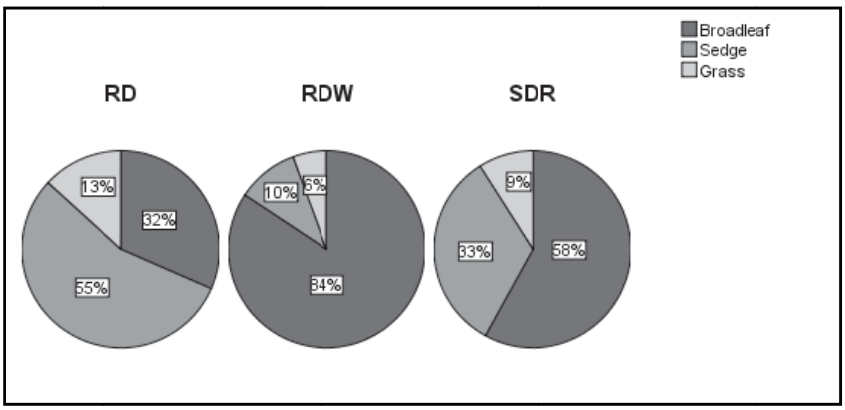

Figure 3. Relative density, relative dry weight and summed dominance ratio of different weed types at Bjena

3.4 Composition and weed dominance in western Bhutan

Table 4. Weed species with family, type, relative density (RD), relative dry weight (RDW) and summed dominance ratio (SDR) in western Bhutan*

Species	Family	Weed type	RD	RDW	SDR
Potamogeton distinctus A. Bennett **	Potamogetonaceae	Broadleaf	0.00	75.37	37.69
Blyxa aubertii (L.C. Richard 1814)	Hydrocharitaceae	Broadleaf	37.90	4.86	21.38
Schoenoplectus juncoides (Roxb.) Palla	Cyperaceae	Sedge	20.67	6.50	13.58
Monochoria vaginalis (Burm.f.) Presl.	Pontederiaceae	Broadleaf	8.36	1.49	4.92
Paspalum distichum L.	Poaceae	Grass	4.88	3.76	4.32
Alternanthera sissilis (L.) R.Br.Ex DC	Amaranthaceae	Broadleaf	6.96	1.37	4.16
Cyperus difformis L.	Cyperaceae	Sedge	5.44	0.15	2.79
Echinochloa spp.	Poaceae	Grass	1.75	3.17	2.46
Fimbristylis littoralis Gaudichaud	Cyperaceae	Sedge	3.83	0.54	2.18
Commelina diffusa Burm.f.	Commelinaceae	Broadleaf	3.99	0.17	2.08
Acmella uliginosa (Schwartz) Cassini	Asteraceae	Broadleaf	2.82	1.10	1.96
Cyperus iria L.	Cyperaceae	Sedge	0.87	0.39	0.63
Rotala densiflora (Roth.Ex R.&S.) Koehne	Lythraceae	Broadleaf	0.84	0.06	0.45
Bidens tripartite L.	Compositae	Broadleaf	0.41	0.33	0.37
Ischaemum rugosum Salisb.	Poaceae	Grass	0.20	0.48	0.34
Arthraxon quartinianus (A.Rich.) Nash	Poaceae	Grass	0.54	0.02	0.28
Cyperus rotundus L.	Cyperaceae	Sedge	0.30	0.10	0.20
Fimbristylis aestivalis (Retzius) Vahl	Cyperaceae	Sedge	0.15	0.12	0.13
Cynodon dactylon L.	Poaceae	Grass	0.09	0.03	0.06

**Average of two seasons*

***Plant count of P. distinctus could not be taken due to difficulty in separating individual plants*

Nineteen (19) different species of weeds from 10 families were identified during 2-season weed survey in Bjena, Wangchang and Guma Geog comprising of eight broadleaves, six sedges and five grasses (Table 5). Broadleaf were the dominant weed types contributing 73% (SDR) to the weed community followed by sedges and grasses, each contributing 20% and 7%, respectively (Figure 4). *P. distinctus* contributed highest to the weed community with SDR 38 followed by *B. aubertii* and *S. juncoides*, each contributing 21% and 14%, respectively. Maximum relative density was recorded with *B. aubertii* while maximum relative dry weight was recorded with *P. distinctus*. Broadleaves shared 61% of the RD and 85% of the RDW, sedges shared 31% and 8%, respectively while grasses shared 7% and 7%, respectively (Figure 4).

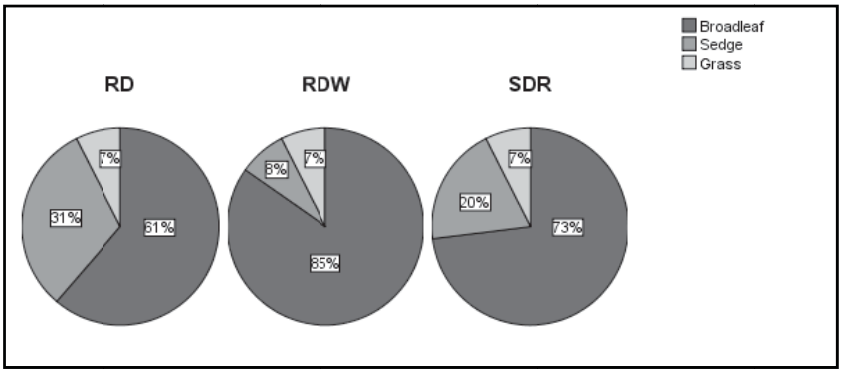

Figure 4. Relative density, relative dry weight and summed dominance ratio of different weed types in western Bhutan

4. Discussion

Weed species that are associated with rice vary with soil, temperature, latitude, altitude, rice culture, seeding method, water management, fertility level, and weed control technology used (Smith and Moody, 1979). Hanafiah et al (1973) concluded that weed community distribution is determined by variation in environmental factors such as soil, climate, altitude, and cultural techniques. Maiti (1977) reported that weed vegetation correlates well with meteorological conditions such as temperature, rainfall, and humidity. Tiwari and Nema (1967) reported that habitat, water status, and the planting methods were primary factors causing weed communities to co-exist with rice. Most important factor determining species composition was considered moisture status following planting (Janiya and Moody, 1982). In Bhutan, 76% of the rice area is rain fed

lowland (Ampong-Nyarko and Datta, 1991). Water is supplied by frequent monsoon rains during the growing season. The amount and distribution of rainfall received for irrigation is uncertain. With such conditions of water availability, the use of water as a tool to control weed growth is severely hampered. About 80% of the rice grown in South and Southeast Asia is subjected to uncontrolled water supply, which exposes the rice land to various degrees of weed pressures (DeDatta, 1981). Upland, semi-aquatic, and aquatic weeds all present problems as observed in our study. The aquatic weed, *P. distinctus* still remains a major problem in Bjena and Guma Geogs. The problem has been eliminated in Wangchang Geog as a result of repeated and extensive hand weeding for several years. However, the problem is replaced by another submerged aquatic weed, *B. aubertii*, which is also seen as an emerging problem in Guma Geog. This weed has not been detected in Bjena Geog.

It is also likely that repeated use of butachlor might have caused problems of broadleaf weeds and sedges as butachlor is mainly used to control grasses. Such ecological shifts have been observed in East Asia, where herbicides have been used continuously on rice for a number of years. For instance, in the Philippines, repeated use of herbicides to control *Echinochloa* spp. and *M. vaginalis* lead to emergence of troublesome weeds such as *Scirpus maritimus* L. and *Paspalum paspalodes* (Michx) Scribner (Moody and Drost, 1983).

Moody and Drost (1983) reported that the weed flora in any rice field was usually about ten species, of which the dominant ones were rarely more than 3 to 4 species. Cyperaceae was the most common family with 6 different species of sedges infesting transplanted rice in Western Bhutan. The most important sedges were *S. juncoides* and *Cyperus difformis* L. The family poaceae followed the next with 5 different species of grasses. The most important ones were *P. distichum* and *Echinochloa* spp. Broadleaves, mostly aquatic weeds were the most dominant among weed types with 8 different species followed by sedges and grasses, each with 6 and 5 species, respectively. The most important weed species in western Bhutan, according to SDR are *P. distinctus*, *B. aubertii*, *S. juncoides*, *M. vaginalis*, *P. distichum*, *A. sissilis*, *C. difformis*, *Echinochloa* spp., *Fimbristylis littoralis* Gaudichaud, *Commelina diffusa* Burm.f., and *Acmella uliginosa* (Schwartz) Cassini. The minor ones are *Cyperus iria* L., *Rotala densiflora* (Roth. Ex R.&S.) Koehne, *Bidens tripartita* L., *I. rugosum*, *Arthraxon*

quartinianus (A. Rich.) Nash, *C. rotundus*, *Fimbristylis aestivalis* (Retzius) Vahl and *C. dactylon*.

5. Conclusion

The study concludes that there are great diversities of weed infestation in transplanted rice in western Bhutan. The highest weed infestation was observed at Guma Geog in Punakha Dzongkhag. The major weeds which are important to rice are *P. distinctus, B. aubertii, S. juncoides, M. vaginalis, P. distichum, A. sissilis, C. difformis, Echinochloa* spp., *F. littoralis*, *C. diffusa* and *A. uliginosa*. Broadleaf weeds dominated among weed types followed by sedges and grasses.

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Upland rice as a potential option to increase rice production in rain-fed dry land farming system in Eastern Bhutan

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Abstract

Upland rice cultivation in Bhutan was an ancestral practice but the extent of cultivation declined over the years. Research and development interventions on upland rice were revived to diversify the dominant maize-based system in eastern Bhutan. The surplus production of maize and the severe outbreak of a new disease in maize were the driving factors for the focus on upland rice since there was a need for a suitable crop for the maize-based system. Research and Development Centre, Wengkhar through its outreach program initiated demonstration of upland rice in potential areas from 2004 onwards. A parallel approach of technology demonstration and evaluation was pursued for up-scaling upland rice. The release of Khangma Maap, which adapts to the upland ecosystem was befitting. An active partnership between research, extension and farmers and BUCAP project and Global Environmental Facility ushered in the dissemination and diffusion of upland rice. In less than a decade, upland rice has proven to be a viable option for enhancing rice production and substitute rice import by 30-50% in remote areas. It also serves as a drought resistant and climate-resilient rice variety in uplands. The national rice commodity program has recognized the scope of upland rice and included upland rice development in the 11 Five Year Plan.

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Keywords: Upland rice, research outreach, dryland system, climate change, impacts

1. Introduction

Upland rice refers to the rice crop grown in the upland ecosystem which is rain -fed bunded or unbunded fields without any surface water accumulation (Singh and Singh, 2000). Upland rice is sown in the dry land fields like maize, wheat and millet (Pandey et. al., 2006). In some areas, seedlings are also transplanted like millet in the dry land. In Bhutan, upland

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rice cultivation was an age old practice in different parts of the country. It was more popular in mid and low altitude areas of eastern Bhutan where irrigated wetland rice are limited. In local terms, upland rice is referred as *Pangbara* in the east and *Kambja* in the western part of Bhutan. In olden days when land was abundant and population was scarce, slash and burn was the dominant farming practice which highly suited *Pangbara* cultivation. However, upland rice cultivation declined over the years for several seasons such as low productivity, declining soil fertility, labour intensive cultivation techniques, intense weed pressure, and government legislation to discourage slash and burn system and conversion to permanent dry land with full ownership of land. Apart from the above technical factors, the availability and access to imported rice has also contributed to the discontinuity of upland rice cultivation.

Towards the end of the 8th Five Year Plan (1997-2002) there was a substantial increase in maize production as a result of the vigorous promotion and subsequent adoption of high yielding variety *Yangtsipa* along with the use of inorganic fertilizers. Majority of the six eastern *Dzongkhags* reported surplus maize production and Food Corporation of Bhutan (FCB) supported the marketing of the surplus production. This scenario prompted the national maize research program to explore a suitable crop that could help diversify the maize based farming system in eastern Bhutan. In 1999, *Khangma Maap,* a blast resistant high altitude rice variety was released in the wake of the 1995 rice blast. This variety was widely promoted in the blast affected areas. Farmers in Kanglung, Trashigang who received small quantity of seed of this variety for cultivation in the irrigated wetland ecosystem had tried it successfully under the upland ecosystem. This was the starting point for the rejuvenation of upland rice cultivation in eastern Bhutan.

RNR-RDC Wengkhar used these indicative results to systematically demonstrate *Khangma Maap* under upland ecosystem firstly under the BUCAP (Biodiversity Use and Conservation Asia Program) project sites where on farm diversity of food crops and improvement of household food security was a primary focus. *Khangma Maap* although released for the irrigated rice ecosystem was found to be equally good under upland ecosystems.

The successful demonstration by the centre in Dremetse, Khaling and Kanglung, caught the attention of many farmers residing above 1500 m

above sea level (asl) in the eastern Dzongkhags. Accordingly, RNR-RDC Wengkhar scaled up the demonstration of upland rice cultivation in collaboration with the Dzongkhags in other potential areas. By 2012, it has become an established crop once again in several places in eastern Bhutan and is contributing towards enhancing rice production and ensuring food security.

2. Materials and Method

A parallel approach of technology evaluation vis-a-vis technology demonstration following the concepts of research outreach outlined in Dorji et.al., 2009 and up-scaling by farmers using *Khangma Map* and few traditional upland varieties. Geogs that traditionally cultivated upland rice and those that were agro-ecologically suitable were identified for Research Outreach Program (ROP) for demonstration of upland rice such as Drepong, Bumdeling, Kanglung, Pemagatshel and Mongar.

A systematic on station evaluation of potential high altitude rice varieties and selected traditional upland rice varieties were carried out in research sub-centre at Khangma. Farmer's field days were organized in the demonstration sites with funds from BUCAP project for farmers and extension staff to help them understand the advantages of upland rice. Seed request from farmers were collected and additional seeds were supplied in the in the following season in collaboration with the geog agriculture extension staff thereby moving from one site to another. BUCAP farmers of Dremetse, Kanglung and Khangma who got the first opportunity to receive seeds and technical support was later used as the source of seed and knowledge for disseminating upland rice technology to more farmers in the region.

Farmers were invited to visit the station trials and Participatory Variety Selection (PVS) from the on station trials were conducted. Farmers were also taught the seed selection techniques during the field days. The varieties that performed well were further evaluated in the farmer's field under farmer's management. Trials on seed rate and time of planting were also carried out to develop appropriate recommendations and package of practices. The on-station trials and on-farm demonstrations were then followed by appropriate extension material development and publications after 3-4 years. The success of the ROP was then scaled up in potential sites in far-flung areas of Mongar and Pemagatshel with supports of the GEF of

the United Nations Development Programme (UNDP) through the formation of upland rice cultivation *Tshogpa* (Group), a community based organization (CBO) for promotion of the crops. Free seeds and technical support was channeled to the farmers using the project funds. Apart from these initiatives from RDC Wengkhar many others Dzongkhags also went all out in disseminating and expanding the cultivation of upland rice through their respective crop promotional programs.

3. Result and Discussion

The research results and the impacts of development interventions on upland rice are discussed in the following sections.

3.1 Research on upland rice

Adaption trials of different rice varieties for upland ecosystem determining appropriate planting date and seed rates were carried out . The research results in detail are elaborated in Katwal et al., (2008) and RNR-RDC Wengkhar (2008). A summary of the research outputs relevant for this paper are as follows:

From the 12 varieties of both improved and traditional lines evaluated for the upland ecosystem, *Machapucharey 3* introduced from Nepal, *Zangthi 1* and *Zangthi 2* local lines from Zangthi geog under Samdrupjongkhar were found to have potentials under the upland ecosystem with an average production of 1.00 – 2.10 t/ha (Table 1). *Khangma Maap* is found to be the best variety for upland ecosystem under farmer's management. Local selection *Zangthi 1* and *Zangthi 2* promising varieties are promoted further in farmer's field. *Chandhannath 1*, another introduced variety from Nepal despite higher yield had lower preferences due to difficulty in threshing while varieties such as local *Sambara, China 7 and Zangthi-3* were found to be *prone to* severe *leaf an*d neck blast and *Yusirey Kaap* had high percentage of grain sterility.

Since upland rice is rain-fed, its planting time has to fit with the onset of rainy season. Ideal sowing time has been identified by studying both rainfall patterns and production trials. For good germination and crop establishment, ideal sowing time for upland rice can be between the last week of March to the last week of April. However, this should not be taken as a blanket recommendation due to large variations in micro climate.

The optimum seed rates of 30 to 60 kg/ha (12 to 25 kg/acre) which can give an average of yield ranging from nearly 1000 up to 1300 kg/acre is recommended for upland rice.

Table 1. Agronomic traits and yield of 12 upland rice varieties

Variety	Flowering days	Plant height (cm)	Yield (t/ha)	Disease
Zangthi-1	175	124.6	2.06	-
Zangthi-2	173	116.0	2.10	Easy to thresh
Zangthi-3	-	111.3	0.00	Severe leaf and neck blast
Sambara Local		133.6	0.00	Severe leaf and neck blast
Yusirey Kaap	170	90.6	0.00	Sterile grain
Yusirey Maap	180	125.6	0.62	
Khangma Maap	170	154.6	1.43	
Chandanath-1	130	122	1.08	Difficult to thresh
Chandanath-3	145	142.6	0.73	
Machapurchrey-3	175	141.6	0.66	
China 4	124	90	0.30	
China-7	100.0		0.00	Severe leaf and neck blast

Source: RNR-RDC Khangma (2009)

Table 2. Yield comparison of upland rice varieties 2010

Variety	Location		Mean yield (t/acre)
	Kanglung Pam	Kanglung	
	Yield (t/acre)	Yield (t/acre)	
Machapucharey 3	1.6	0.8	1.2
Chaandanath 3	0.72	0.51	0.6
Zangthi-1	0.91	0.92	0.9
Zangthi-2	0.91	1.23	1.1
Khangma maap	0.89	1.21	1.1

Source: RDC Wengkhar (2010-11)

In the 2012, four potential varieties composed of two introduced and two locally selected upland rice varieties were evaluated in large observation plots under farmer's management in Kanglung and Kanglung Pam in permanently cultivated dry land. The performance of all the

varieties was reasonably good as compared to the standard check variety *Khangma maap.* The highest yield of 1.2 t/acre was recorded for *Machapucharey 3* as compared to 1.1 t/acre produced by *Khangma maap* (Table 2). The two local selections *Zangthi 1* and *Zangthi 2* also produced comparable yield. These varieties will be further evaluated and the best one will be proposed for release.

3.2 Impact of upland rice cultivation

One of the major impacts of the upland rice in the region can be understood from its expansion from research station to farmer's field particularly to far-flung areas. Rice varieties namely *Khangma Maap*, *Machapucharey 3*, *Zangthi 1* and *2* were taken to on farm research sites in Trashigang (Khaling, Kanglung, Bartsham), Mongar (Dremtse, Mongar Phosrong, Drepong, Kengkhar, Jurmey), Lhuntse (Jarey), Yangtse (Bumdelling), Samdrupjongkhar (Lauri and Serthig) and Pemagatsel (Zobel and Chimong).

An analysis of the trend in the uptake of cultivating rice under dry land – upland indicated successful revival of upland rice cultivation. What began on a small scale on farm trial in Kanglung, Trashigang in 2004 and Phosrong, Mongar in 2006 had spread to about 13 different sites across the six Dzongkhags by 2011.

Annually, about 400-500 kgs of seeds were supplied from RDC Wengkhar alone and about 700 households in 28 gewogs so far have taken up upland rice cultivation successfully covering an estimated area of over 254 acres with seeds procured by Dzongkhags from NSC Paro. There has been increase in area of cultivation ranging less than a *langdo* (0.33 ac) per household to more than an acre now. On the request of the upland rice cultivation *tshogpa* of Norbugang Geog, Pemagatshel, an upland rice producing CBO that was developed with support from GEF, UNDP. The Dzongkhag agriculture sector facilitated the lease of government land to grow upland rice. Another significant impact is from the contribution of upland rice in reduction in the purchase of imported rice from shops especially in far-flung remote geogs like Gongdue and Silambi. According to farmers who have started upland rice cultivation, their rice has been substantially reduced by 30 - 50 % as they meet their demand from the upland rice produced in their field.

Some of the notable cases of the revival and its impacts at household levels are presented in the following cases:

Case 1. Upland rice in Kanglung, Trashigang 2004: The beginning of the revival. (*Source: Wangdi, 2005*)

With most research works on upland rice carried out in Khangma Sub-centre, Kanglung village happened to be the first where revival began. One farmer, Ap Naku aged 64 is a retired service personal living with his family of nine. They cultivated their two acres of dry land on which maize, potato and some vegetables were the main crops. Maize was cultivated mainly for food while some parts of potato and vegetables were sold at the local market to buy rice and essentials. He received about 500 grams of *Khangma Map* seed which by then was given for promotion to farmers' field as upland variety. Using his traditional practices of seed broadcasting method, a small trial began. After many years, he saw for the first time notable results. A single hill produced about 8-10 tillers with which a total of about 40 kg was harvested from his trial, which took him by surprise. His neighbours took some of the yield for seed and then up-scaled cultivation to about 0.66 acres in the following season of 2005 giving him about 600 kg (about 1200 kg per acre). This yield was sufficient for him for the winter in which he did not have to buy any rice while he could also feed the straw to his cattle. By then, more farmers came to him looking for seeds. He directed them to the extension office and the research centre. In 2005, he renewed rice seeds from the research centre by taking 5 kg and cultivated on the 0.66 acre rotating with maize and potato. By the end of 2005, geog extension centre recorded a total of 60 households cultivating 12 acres of rice variety *Khangma Map* with an average yield of about 1000-1200 kg per acre.

The red color of the grain, good taste and performance of the variety in dry land conditions led to the uptake and the only problem faced by the farmers were few incidences of white grub infestations but it was not severe to discourage them. Farmers of Kanglung still continue to cultivate the variety. Today, upland rice is cultivated in more than five geogs covering a total area of about 45 acres in Trashigang.

Case 2. From Kanglung to Mongar and beyond, 2004 to 2010 (*Source: Wangchuk et al., 2011; Dorji, L and Katwal, T.B. 2009; Choney, 2009.)*

With the shifting of the RNR Research Centre in the east from Khangma, Trashigang to Wengkhar, Mongar in 2004, the ROP on upland rice was expanded to areas beyond Khangma.

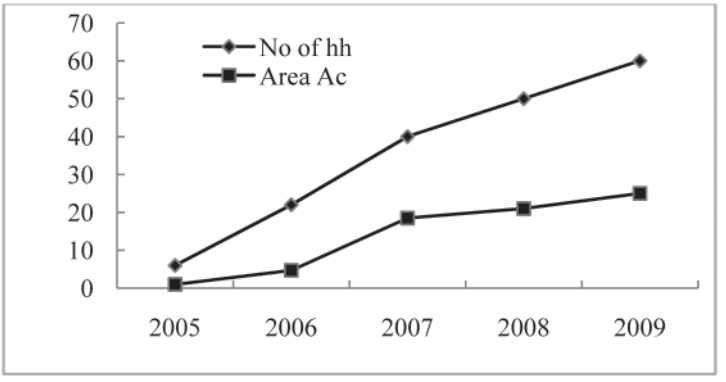

Figure 1. Trend in the number of households and production area for upland rice in Depong geog

Some exemplary cases of a successful ROP on the promotion and up-scaling upland rice are from Mongar and Depong geog under Mongar Dzongkhag. The centre using the outreach concepts of promoting crops through on farm research and demonstration began the continuation of upland rice promotion with a farmer Sangay in Tasanglung (2050 m asl) under Mongar geog in 2004. By 2005, the upland variety Khangma Map spread to Laptsa village (>1800 m asl) under Depong geog of Mongar Dzongkhag. By involving farmers of a potential areas in field days and demonstration activities conducted in partnership with the geog and Dzongkhag Agriculture extension, the field crops research sector managed to initiate a cumulative process of increasing more areas and farmers in the geog through which about 50 farming households in Laptsa village had put some 21 acres under Khangma Map cultivation by 2008 (see Figure 1). By 2009 more than 60 farmers have brought their 25 acres under cultivation.

Maintaining the process of involving potential growers of the following season in field days conducted at the previous year in collaboration with extension centers using farmer to farmer extension methodologies, Khangma Map spread beyond Depong geog by 2009 into areas such as Tsamang, Tsakaling, Kengkhar, Thangrong, Chaskhar,

Jamcholing, Broksar, Dremtse all under Mongar Dzongkahg and then to Khaling under Trashigang. By then, Khangma Map was cultivated in more than 50 acres with average yield of 1-1.8 t/acre.

Khangma Map cultivation as upland rice further moved into more areas where upland rice used to grow. In 2010 onwards, places such as Tshelinggor, Zobel, Chongshing geog and Chimong geog under Pemagatshel had also taken up the variety with more than 60 farming households harvesting average yield ranging from 0.7 to 1.3 tons per acre.

Case 3: Supplementing household food at times of disaster with upland rice: The case of Tsanglung Mongar and Bumdelling, Trashiyangtse in 2006(*Source: RNR RDC Wengkhar, 2005 and Wangchuk etal., 2010*)

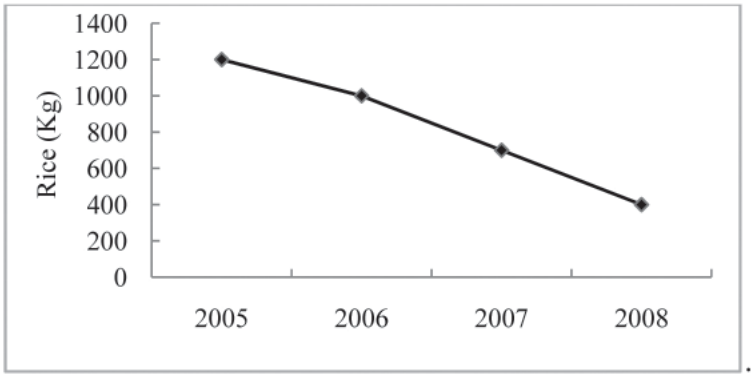

Figure 2. Trend in rice purchase in farmers adopting upland rice.

In 2004, a flash flood in Bumdelling valley under Trashiyangtse damaged the wetlands thereby reducing the rice cultivation. RNR RDC Wengkhar in 2005 demonstrated upland rice cultivation in small plots which gave good results following which in 2006 farmers began cultivating two varieties Khangma Maap and Machapucharey 3 with average yield of 0.9 t per acre and 1.7 t per acre for Khangma Maap and Machaphucharey 3 respectively . After this, Bumdelling geog had been able to cultivate the varieties covering 4-5 acres.

In 2006, maize in higher elevation above 1700 masl was severely affected by fungal diseases namely Turcicum Leaf Blight and Gray Leaf Spots. A farmer Sangay who began experimenting in 2004 took another step in intercropping Khangma Maap with Potato and maize crops. Since

maize yields declined with disease infestations, his household grain requirements were supplemented with the upland rice thereby reducing his rice purchase by almost 50%. Like him, others who took up upland rice were also able to reduce their purchase of rice from shops (see Figure 2).

Case 4: Reviving upland rice in Kheng (Mongar), Norbugang and Dechenling (Pemagatshel)

Poverty incidences and food shortages are generally more severe in remote geogs and therefore, RNR RDC Wengkhar having successfully worked on research and development in upland rice initiated with a small grants program focusing on four furthest geogs in the region i.e. Silambi, Gongdue under Mongar Dzongkhag and Norbugang, Dechenling under Pemagatshel Dzongkhag. The project titled "Promoting upland paddy and vegetables: Ensuring food security through diversification of crops in dry lands of remote geogs of eastern Bhutan" implemented from June 2009 to June 2012 has been the major factor in spreading the upland rice varieties in these remote geogs.

Through this project interventions and Dzongkhags crop promotional programs under upland rice component; more than 100 farmers have revived the cultivation of upland rice adopting the new variety Khangma Maap. By 2012, more than 80 acres are brought under cultivation with average production areas ranging from 0.33 acres to 1 acre harvesting average yield of 0.648 to 1.05 t/acre (See Table 3).

Table 3. Impacts of upland rice in four remote geogs of eastern Bhutan

Indicator	Mongar		Pemagatshel		
	Silambi	Gongdue	Norbugang	Dechenling	Total
Number of farmers	66	28	12	23	129
Production area (acres)	60	6	11	7	84
Average crop yield (t/acre)	1.05	0.95	0.64	0.87	

Interventions in reviving upland rice in Silambi has impacted on the re-cultivation of fallow lands which otherwise would have been kept

without any production. These remote areas depend mostly on maize as a food crop and rice is mostly purchased from the shops situated 2-3 walking days away from their village. Rice in Silambi brought from Lingmethang (3 days walk) costs about Nu. 65-70 per kg is one of the most expensive commodities. The upland rice cultivation on average has reduced the rice purchase by 40% enabling farmers to have good quality food grain supplement locally produced by themselves and upland rice has a good prospects in rural communities.

3.3 Farmer's perception on upland paddy

Participatory evaluation of the varieties encourages farmer to farmer sharing of experiences, observations and assessment of the technologies. The characteristics of *Khangma Maap*; red colour, good taste and versatility to adapt in the steep dry land has encouraged farmers to grow this variety. In 2007, maize diseases (*Gray leaf spots and Turcicum leaf blight*) caused considerable losses to the entire maize growing areas and threatened the household food security of many farmers. In such a situation, upland rice was promoted as one of the means to supplement the food shortages in many affected areas. Some of the farmers' perception on the cultivation collected during farmers' field days is shown in Table 4.

Table 4. Advantages and disadvantages of upland paddy based on farmers' perception

Advantages	Disadvantages
• A good option to produce rice for farmers who do not own wetlands • Contributes to enhance household food security and reduces the purchase of imported rice • Paddy straw can be fed to cattle and is more palatable than maize stover • A suitable option for the maize-based cropping system especially as maize is being affected by severe diseases • Crop guarding is easier than in maize or other crops • Suitable for steep unused land and requires less water as it is completely rain-fed • A good option to re-cultivate the fallow *tseri* land • Cultivation is easier without having to transplant	• Labour intensive as weed pressure is one of the major production constraint • Severely prone to damage by birds prior to harvest and white grubs at vegetative stage • Less yield and does not have multiple uses like maize • Lack of quality seeds • Not suitable for small land holders unlike maize

3.4 Driving factors for rapid up scaling of upland rice cultivation

One of the main driving factors among others was the need of a suitable crop to diversify the maize based system in the back drop of surplus maize, lack of attractive price and absence of a reliable marketing mechanism. This situation urged research to explore opportunities to identify a suitable crop which was offered by upland rice. In addition to these several factors that favoured the rapid promotion and adoption of upland rice technologies are:

- Availability of a suitable red rice variety *Khangma Maap* that could adapt very well under upland ecosystem at an elevation (2300 masl).
- The pursuance of a concerted focused research outreach program on upland rice and the success of the ROP lead by RNR RDC Wengkhar for demonstration, dissemination and promotion
- On-farm demonstration of cultivation technologies, supply of seeds and farmer to farmer contact through field days with funds from the BUCAP project
- Large parcels of land that were used as *Tseri* was available
- It can be grown organically and can fetch better price as compared to the rice produced conventionally
- It provided an opportunity for farmers without wet land to cultivate rice which is the most preferred staple
- Recognition of the potential of the technology by the Dzongkhgas and vigorous promotion of the crop by the extension services through supply of free seed
- Fund for promotion of upland rice in remote areas was supported through UNDP- Global Environmental Facility (GEF) was available
- Upland rice has proven to be a suitable niche crop for diversifying the maize-based system. Maize–upland rice rotation can be suitably adopted in areas above 1500 masl to break the continuous mono cropping of maize that has intensified the buildup of inoculums for the epidemic outbreak of Gray Leaf Spot (GLS) and Turcicum Leaf Blight (TLB) diseases of maize

3.5 Development of research publications

The availability of information on upland rice was very scanty except for a brief survey report conducted by erstwhile RNR Research Center Khangma. As the research outreach program accelerated there was an increasing demand from the different stakeholders for technical information on upland rice. Accordingly RNR RDC Wengkhar took the initiatives to package research information into different publications. One of the visible impacts of the ROP upland rice has thus been the documentation and development of useful publications that serves as a repository of information for reference and future research work. A list of publications developed is shown below:

- Upland Rice in Eastern Bhutan, Prospects and Perspective, RNR Research Centre Wengkhar Technical Document 38/FC/2008 RNR RC Wengkhar
- Revival of Upland Paddy (Kambja) cultivation: A case of diversifying maize-based cropping system and enhancing household rice self-sufficiency. Sanam Drupdrey, March 2011. ICS, MOAF
- Upland Rice Technology helps farmers produce their most preferred staple food in eastern Bhutan: reviving Pangbara with research interventions. RNR RDC Wengkhar News and Views, Issue 18, Jan-March 2007
- Upland paddy cultivation, reintroducing the crop in farmer's field. CoRRB News Letter, MoAF Vol VIII, March 2009
- Upland rice becoming popular in the east, an update. CoRRB News Letter, MoAF. Vol II, Issue 4 December, 2009
- Upland paddy cultivation practices. RNR Extension Material 2010. RNR RDC Wengkhar

4. Conclusion

A small initiative on demonstration and promotion of upland rice mostly in eastern Bhutan has shown that it can make a substantial contribution to the household food security. The impacts of upland rice firstly demonstrated the benefits of channeling research and development interventions in a crop which is a "minor cereal". Upland rice can be a suitable niche crop to diversify maize-based system and contribute to supplementing household food sufficiency and help reduce rice import in remote areas. However, upland rice with lower yields and less diverse uses

compared to maize cannot be a substitute for maize in dry land systems. The availability of resilient and versatile rice varieties both improved and locally selected which is suitably adapted in the upland ecosystem can substantially helps increase rice production. In the back drop increasing water scarcity, the versatile upland varieties with good adaptation to local conditions can also provide some options for adaption to the increasing threats of drought and climate change in rice production. Upland rice mostly grown in remote and far-flung areas, where use of inorganic inputs is minimum. It has also high potentials as a niche organic crop from the remote areas.

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Evaluation of pheromone lures, traps and nuclear polyhedrosis virus against chilli pod borer in Punakha

Kiran Mahat[8], Phuntsho Loday, Lhendup Dorji

Abstract

Chilli pod borer is an important pest of chilli particularly in the early season crop. This study evaluated pheromone lures and traps and bio formulation, nuclear polyhedrosis virus, against combating the pest. Field studies using the pheromone lures and traps were conducted from 2009 to 2012 and nuclear polyhedrosis virus was evaluated in 2009 in Kabesa, Punakha. The pheromone traps evaluated as a population monitoring tool provided information on the emergence, peak activity and cessation of activity of the moths in chilli. Results from the capture of male moth in the traps indicate that the moths emerge from the third week of March to May. Egg counts on chilli plants indicated the peak egg laying period commences from April to May. These results suggest that management strategies should be targeted from beginning of April to May. The results strongly indicate its effectiveness as pest monitoring and mass trapping tool. Nuclear polyhedrosis virus, however, requires re-validation as it was effective in reducing pod borer damage in a plot only. This paper discusses seasonal phenology of Helicoverpa and its appropriate management strategies.

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Keywords: *Helicoverpa armigera*; Chilli; Pheromone traps; NPV; Control

1. Introduction

Helicoverpa armigera Hubner (commonly known as chilli pod borer in Bhutan) is distributed worldwide and is a serious polyphagous pest causing huge yield losses in a wide range of cultivated crops. In Bhutan, Helicoverpa is a major pest in early chilli crop and tomato and also occurs on maize and pulses. The damage in chilli is causes by the newly hatched larvae which enter inside the chilli pods for feeding. Larva feeding can predispose fruits to fungal and bacterial infections causing fruit drop.

Helicoverpa has been reported to have developed resistance to a wide range of insecticides and has therefore become a difficult pest to

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control (Pree and Daly, 1996; DPI&F, 2005a, Armes et al., 2006). In Bhutan, development of resistance to insecticides by Helicoverpa has not been documented so far. However, the use of insecticides, particularly organophospahates and pyrethroids, is rampant in the early chilli crop season. For instance, farmers on an average apply four to five cover sprays in a season in the early chilli crop in Punakha valley (personal communication).This practice over years can potentially dispose the pest to develop resistance to the commonly used insecticides and hence warrants the need to investigate alternate strategies which apart from being effective is also environmentally friendly and economical. The current recommended practice to manage this pest advocates mechanical (destruction of the immature stages of *H. armigera*), cultural (deep plowing to destroy the overwintering stage) and chemical control (insecticidal cover sprays).

Apart from these existing recommended control strategies, no alternate control strategies, which can potentially minimize reliance on insecticides, have hitherto, been investigated against this insect pest. Therefore, control strategies employing pheromone lures and use of entomopathogens such as Nuclear Polyhedrosis virus (NPV) holds promise. NPV are known to be very specific to Helicoverpa, and unlike synthetic pesticides has no residual toxicity and adverse effect on beneficial insects, humans and the environment (Gröner, 1996). In addition, so far no reports on resistance build up to NPV by Helicoverpa has been documented (Jones, 1994). Pheromone lures are also species specific and when deployed in the field in large numbers annihilates the male population and reduces the female moth's chance to mate and produce viable eggs. This subsequently suppresses the population of the pest organism. In addition, it can also be employed in the field for determining the population dynamics of the pest which in turn can assist in devising and timing appropriate management strategies. This study evaluated the efficacy of the pheromone lures and traps in providing information on the population dynamics of Helicoverpa in chilli in Kabesa, Punakha. In addition, it evaluated the field efficacy of NPV in controlling this pest in chilli.

2. Materials and Method

2.1 Study area

The chilli pod borer control trial using NPV was carried out in Damchi village, Kabjisa Geog under Punakha Dzongkhag in 2009. The

pheromone trapping study was set up in different localities in farmer's fields within Kabjisa Geog between 2009 and 2012 for establishing efficacy of the pheromone lures and traps in providing information on the population dynamics of Helicoverpa in chilli. These experimental sites were located approximately at an altitude of 1300m above sea level.

For the NPV trial 4 farmer's fields were selected (hereby referred as F1, F2, F3 and F4). Each field consisted of a treated plot and a control. These fields were not advocated with any cover sprays. The four field sites were selected in separate locations within Damchi village in order to target possible differences in population pressure of the pest organism within these areas. Both the control and treated fields consisted of two large fields with approximately 10-15 raised beds in each field. The raised beds were 1m x 3m in size with 4 rows of chilli. The number of raised beds varied between the four sites because of the difference in size of the farmer's field. The treated and control plots were laid at least 100m apart. The chilli seedlings were sourced from the farmers and transplanted in the first week of April. The four field sites were selected in separate locations within Damchi village in order to target possible differences in population pressure of the pest organism within these areas.

2.2 Pheromone lures and traps

The pheromone lures and traps were procured from Pest Control (India) Pvt. Limited (PCI, Bangalore, India). The lures and traps (Fero-T™) were set up 10-15 cm above the chilli plant canopy. Data on the moth captures in the traps were recorded on a weekly interval from the traps.

2.3 NPV application and sampling

NPV (Helicide®) was supplied by PCI, India. Treated plots were applied with NPV @ 1ml per liter of water mixed with few drops of optical whitener/Robin blue and 15-20 grams of jaggery per 15-16 liters of water. Three sprays were carried out with the first spray on 20/04/2010 when the plants had started flowering and the next two at an interval of 7 days each. NPV was sprayed in the evenings after 3 pm to avoid possible NPV degeneration by UV rays. No treatment was advocated in the control plots. At every 8 days interval, 15 plants were randomly sampled, from both the treated and control fields, and the number of eggs and larvae were recorded. In addition, 50 pods were dissected for larval infestation, from the treated

and control plots, and dead larvae due to NPV infection showing typical NPV symptoms, (larvae that have crawled towards the top of the plant, heads hanging outwards, ruptured integument with slimy brown liquid) (DPI&F, 2005b), were recorded. At every harvest time (in some areas up to 6th harvests) 100 pods were randomly dissected from the farmer's fields from Kabesa to observe pod borer infestation levels in 2010.

2.4 Statistical analysis

The mean percent pod borer infestation data from the control and treated fields were analyzed using a statistical program. Data was analyzed using the SPSS (version 16.0). Prior to analysis, normal distribution was tested using the Kolmogorov-Simirnov test and homogeneity of variances was tested using the Levene's test. Mean percent pod borer infestation data was subjected to a *t*-test comparison. Differences in treatment means were considered statistically significant at the $P = 0.05$ level.

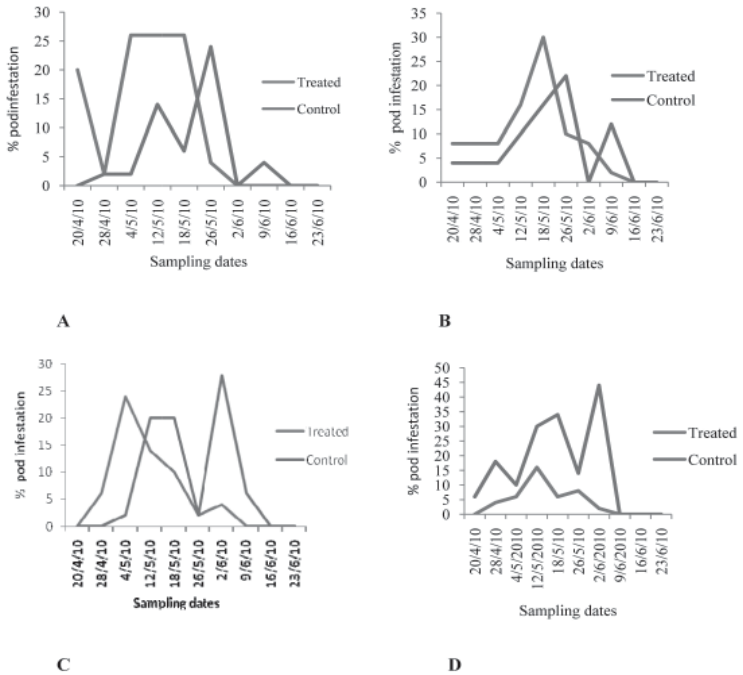


Figure 1. Percent pod borer damage by chilli pod borer, Helicoverpa armigera obtained in the treated and control fields after dissecting 50 pods at each sampling period (A) Farmers field-1 (B) Farmers field-2 (C) Farmers field-3 (D) Farmers field-4

1. Result

A *t*-test comparisons showed no significant difference in the mean percent pod borer infestation levels between the control and the treated plots in the three fields F1 (*t16* = 1.163, *P* = 0.262), F2 (*t16*= 0.518, *P* = 0.661),

F3 (*t16*= 0.518, *P* = 0.661) (Figure 1 A, B & C). However, in the fourth field a significant difference was detected between the control and the treated fields F4 (*t18* = -2.185, *P* = 0.042) (Figure1 D). As per the egg laying data, the egg laying period started right from the first sampling date, that is the third week of April and ceased by the second week of May in all the fields (Figure 2 A, B, C, and D). The pheromone capture results show that the moths begin to emerge from the third week of March as obtained from the 2012 data (Figure 3C). From this period on, the peak activity continues till the third week of May. The pheromone capture data for 2011 was very low and is therefore not included.

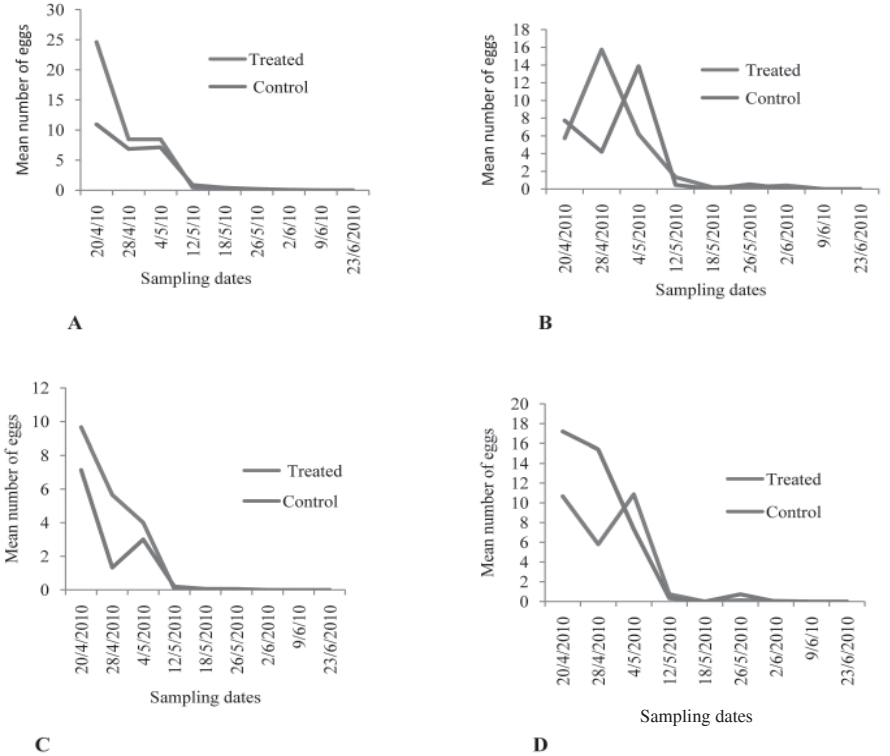
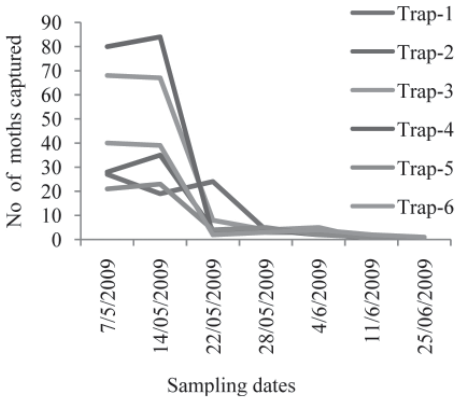
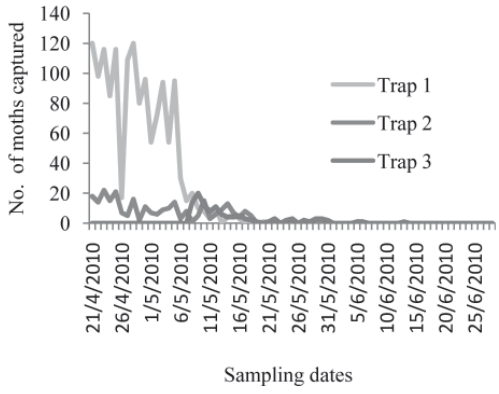


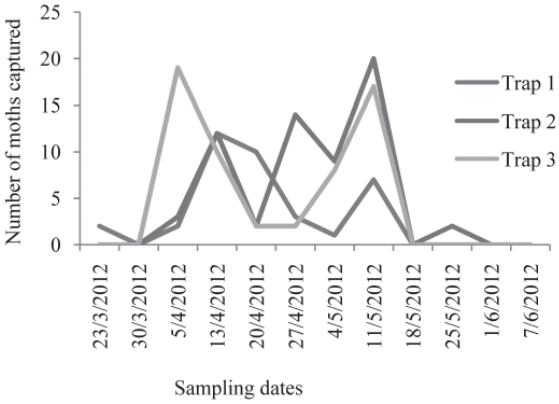
Figure 2. Mean number of chilli pod borer, Helicoverpa armigera eggs observed from randomly sampling 15 plants from each of the treated and control fields



A (2009)



B (2010)



C (2012)

Figure 3. Number of adult chilli pod borer, Helicoverpa armigera captured in pheromone lure traps in 2009 (A), 2010(B) and 2012 (C) chilli cropping season in Kabesa, Punakha

2. Discussion

Helicoverpa causes significant damage in the early season chilli crop. Data obtained through randomly sampling 50 pods in the control plots at different harvest dates in Kabesa Geog in 2010 shows damage levels on chilli pods can be as high as 45% (Figure 4). Similarly, sampling 100 pods randomly in the farmers field in Kabesa Geog in 2010 showed damage levels up to 70% (Figure 5).

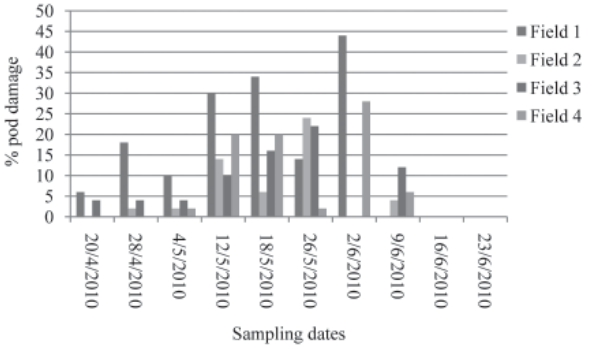


Figure 4. Percent chilli pod infestation by pod borer from 50 pods at harvest from the control fields in Kabesa, Punakha in 2010

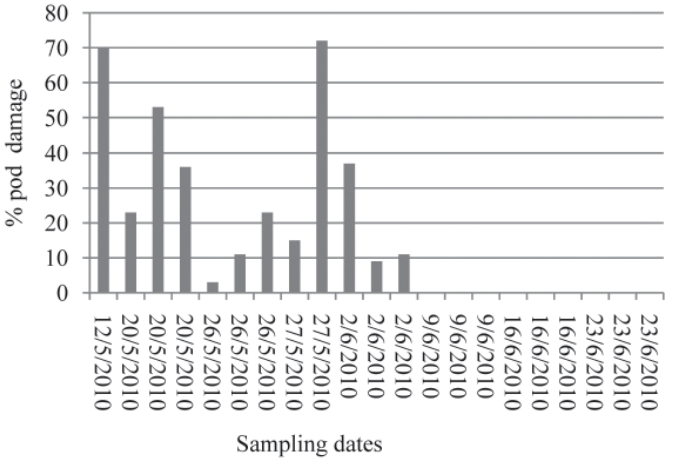


Figure 5. Percent chilli pod infestation by pod borer from 100 pods at harvest from different farmers field in Damchea, Kabesa

Prior to devising any type of pest management strategy, it is important to have a clear understanding of the seasonal phenology of a pest.The phenology of Helicoverpa in chilli in Punakha valley is poorly understood and has not been documented thus far. The data generated through this study, carried out using pheromone lures, traps and visual egg counts on chilli plants, provides information on Helicoverpa emergence, peak egg laying period, peak activity and period of cessation of its activity in the field. In addition, this study presents findings on the field evaluation of a bio-formulation, Nuclear Polyhedrosis virus (NPV), against this pest.

Field deployment of pheromone lures and traps proved effective in capturing field male population of Helicoverpa. Pheromone trapping data from the 2012 cropping season indicates that the male moths begin to emerge from the third week of March and its activity is observed to last till the third week of May (Figure 3C). This was the period when maximum captures in traps were observed indicating it to be the peak activity period of the pest. The results indicate that this product can be used effectively in the field for population monitoring and mass trapping of Helicoverpa. For population monitoring purpose, 2 pheromone traps /langdo or around 5 traps /acre can be deployed. However, for mass trapping the trap density will have to be increased depending on the pest pressure and the costs involved. The pheromone lures lasts for a month in the field and has to be replaced every month.The traps can be reused over two seasons if used properly.

Helicoverpa eggs were observed when the chilli plants were small and had just started flowering. This shows that the moths had started laying eggs right after transplanting, and prior to the commencement of our first egg sampling date (20th April) in 2009. This indicates that the first egg laying period would probably start from the end of March when the first males, that starts to emerge during this period, would mate with females which would then start laying eggs after it matures in the ovaries. The egg laying period started to cease from the second week of May, after which few or no eggs were observed on the plants.

The application of NPV showed a significant reduction in pod borer infestation, between the control and treated plots, from only one of the four experimental plots (Farmers field-4) (Figure 1D).The other three experimental plots did not show any treatment effect. Also, a very low count ($\leq$ 1) of typical NPV infected larvae(dead larva with hanging head

and ruptured integument) were observed in the NPV treated fields. Hence, the efficacy of NPV, to cause larval mortality and provide effective field control, needs to be revalidated both through field and laboratory assays. NPV is a bio-formulation widely used in controlling Helicoverpa in conjunction with other environmentally-friendly techniques. In cotton, genetically modified crop (BT cotton) in conjunction with NPV sprays and augmentative releases of Trichogramma is a common strategy employed to manage Helicoverpa in many parts of the world (DPI&F, 2005b). Such strategies can significantly reduce the reliance on synthetic pesticides that can have an adverse effect on human health, non-target organisms and the environment. However, NPV unlike synthetic pesticides is not very persistant in action and stable, as it denaturates easily when exposed to solar UV radiation (Cherry et al., 2000). Hence, field application of this product in future experiments needs be carried out meticulously, and possible measures to circumvent degredation, while being transported from India and/or during storage, should be taken.

The combination of moth activity and egg laying data indicates that interventions targeted against this pest must be aimed during this peak activity period. NPV is effective when the larva is small (DPI&F, 2005b) and since eggs would hatch continuously through this period NPV applications, deployment of pheromone traps, cover sprays or any other pest management strategy should be carried out in a manner to cover this activity period. These interventions requires to be aimed from the beginning of April extending up till the end of May. If careful egg monitoring on the plants can be carried out, these intervention should start as soon as the first Helicoverpa eggs are observed on the plants. In chilli in Punakh, high levels of parasitism by Trichogramma on on Helicoverpa eggs have been observed (personal comunication). Insecticides should therefore be used judiciously as these parasitiods are highly sensitive to it. However, with frequent occurrence of this pest and to avoid serious yield losses during high pest pressure seasons, the use of insecticides can not be renounced completely. Therefore, management strategies should commence once the moth population crosses the economic threshold level. The tolerence level for this pest is very low, therefore the economic threshold level for Helicoverpa in Chilli has been set at 1.46 larvae/plant(Shivaramu and Kulkarni, 2008).

Finally, repeated use of insecticides can lead to resistant build up by this pest organism. Therefore, strategies in managing this pest should focus on employing alternative techniques which minimises the over all reliance

on insecticides. Deployment of pheromone traps to monitor the field population will provide information on when to start management strategies in differnt agroecological zones. In addition, laboratory rearing and field releases of Trichograma to augment the existing population in conjunction with non-toxic strategies like the use of NPV can be employed. Other strategies like pupae busting wherein the pupae in the soil are destroyed by ploughing the field after harvest (in autumn) and winter flooding to kill these overwintering pupae are recommended. Areas in and around the chilli field should be clean weeded as these pests are polyphagous and can survive on numerous hosts in which they can lay eggs, feed and proliferate. Eggs of Helicoverpa can be easily identified. Freshly laid eggs are whitish in colour which gradually turns light brownish and finally darkish as the the head of the larva inside the egg turns black before hatching(DPI&F, 2005a). Hence, manual picking and destruction of eggs, usually laid on the leaves, inflorescence, flower buds and stem is recommended.The use of traps crops as a sink to lay eggs can be adopted and is a common practice against Helicoverpa. Reports on the use of marigold as a trap crop in Tomato have showed a significant reduction in damage by Helicoverpa (Srinivasana et al., 1994; Phuntsho, 2012). All these strategies if combined can form an overall integrated pest management approach in controlling this pest and reducing yield losses.

3. Conclusion

This study provides important information on the critical life stages of Helicoverpa*,* infesting chilli in Punakha, wherein management stragies if focused during this period can significantly help reduce yield losses. The use of pheromone lures and traps proved very effective in monitoring the population dynamics of this pest, and can also be employed in mass trapping technique. The use of NPV against helicoverpa, however, warrents field revalidation, after which proper recommendations can be established.

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Morphological characterization of Asian Pear and its production potential

Khampa[9]

Abstract

Horticulture is considered as the potential industry of the future in Bhutan. Among the fruit crops, Asian pear is fast gaining importance among the growers in eastern region. However, without clear understanding of their morphological characteristics and production potential, it is difficult to promote the crop. Three trees each of six introduced Asian pear varieties were randomly sampled for the study. No significant difference was observed in tree height and trunk girth among the varieties. Significant difference was found in canopy area with maximum mean of 19 m^2 in Shinko and minimum of 12 m^2 in Yakumo variety. The varieties showed significant difference in leaf length with maximum of 12 cm in Shinko. The leaf width ranged from 6 cm in Hosui to 8 cm in Atago. The petiole length resulted significant difference among the varieties. The fruit weight was highly significant among the varieties with highest mean of 683gm in Atago and lowest of 229 gm in Kikusui. In fruit size, Atago (94,115) was the largest and Kikusui the smallest (70, 81).The fruit shape ranged from oblate (Atago) to oval (Yakumo).Total soluble solids content of the fruit ranged from 10% in Shinko to 13% in Atago.Wengkhar-Lhee 1 had highest firmness of 4 kg/cm^2 and Hosui with 0.77 kg/cm^2. Shinko had high production potential of 104 kg/tree with maximum marketable fruits. This study provides preliminary information for selection and promotion of superior varieties.

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Key words: Asian pear; Morphological characteristics; Yield; Total soluble solids; Production potential

1. *Introduction*

Pears are found to be grown from 755 to 2700 meters above sea level (asl) but majority are found in warm temperate to temperate region of Bhutan, occupying an area of 902 acres and producing 758 metric tons (mt) of fruits (DoA, 2010). The species include; Pyruspahia, Pyrusserotina and Pyruscommunis *(*Krause et al., 2007), and the fruits are mostly unpalatable

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and unmarketable. The local pear adds to fruit diversity in the country and its adaptability to local conditions makes it suitable rootstock for improved Asian pear (RNR-RC Wengkhar, 2007).

There are 11 varieties of exotic Asian pear (Atago, Wengkhar Lhee 1 (*Chojuro*), *Hosui, Kikusui, Kosui, Megeitsu, Niitaka, Nejiseiki, Okusangkeichi, Shinko, Yakumo*) under study at RDC, Wengkhar (DoA, 2011). However, limited efforts have been made to study comprehensively their characteristics and production potential (both marketable and non-marketable). Therefore, this study attempts to characterize morphology of the existing exotic Asian pear varieties and assess their production potential. The result generated from the study will serve as a baseline data for selection and promotion of these varieties in the field.

2. Material and Method

The study was conducted in the research plot of RNR-RDC, Wengkhar situated at 1700 masl. Six varieties of pears (*Atago, Wengkhar Lhee 1, Hosui, Kikusui, Shinko, Yakumo*) from the existing germplasm were selected for the study. The morphological characteristics (tree height, trunk girth, canopy, leaf size, fruit size, fruit weight and production potential (kg/tree)and yield (marketable and non-marketable) were collected randomly from the selected three trees per variety. As additional information, TSS and fruit firmness was also measured for fruits. The tree height was calculated using formula $H = D \tan \theta + HI$ (D: Distance between reader and tree; tan θ : clinometers angle reading and HI: tree height reading by clinometers). A trunk girth was measured at a height of 40-50 cm from the ground.

Tree canopy area was estimated using formula $(m^2) = pi\ (r^2)$ where pi=3.14 and r is radius of the canopy. The leaves were randomly selected from top, middle, bottom and inner canopy of the tree. The leaf length (cm) was measured from the joint of petiole to the tip end of the leaf margin and width was measured at three cross sections : one from the broadest parts and other two from the upper and lower narrow parts. The mean of three readings was taken as the width. The matured fruits were harvested from upper and lower tree canopy and 20 fruits were randomly selected for fruit quality measurement (Ledesma and Carpena, 1987; UPOV guidelines, 1994; CEC and IPGRI, 1983). Fruit weight (kg) was determined using weighing balance. The fruit length was measured from the end of the fruit

pedicel to the tip of the fruit and fruit width from the broadest parts of the fruits (Opondo, 2011) using the absolute solar digital calliper- Mitotoyo, Japan. The fruit firmness (kg/cm^2) and TSS (%) were measured using Penetrometer and Refractometer (ATAGO N-1E Brix 0-32% Japan), respectively. The production potential was assessed as total harvest of fruit (yield/tree) and graded into marketable and non-marketable in kilograms. One way ANOVA test was used for statistical analysis using SPSS (16.0).

3. Result and Discussion

3.1 Tree characters

No significant difference was observed in terms of tree height among the varieties (P = 0.474). The maximum mean tree height was recorded for *Atago* 4.03 m (n = 3) and minimum for *Yakumo* (3.16 m) (Table 1). This is in contrast to findings that have indicated significant differences in the height of Asian pear varieties (Reighard et al., 2008). This might be due to difference in tree management techniques such as training and pruning systems adopted and rootstock species used. Most Asian pears (Japanese variety) are dwarfed (about 50%) on *Pyrus communis* rootstock (Beutel, 1990). The type of rootstock used, training and pruning also determine the tree height. For instance, the vase shape or open centre trained trees tend to be shorter while trained to central leader are fairly tall. The sampled Asian pear varieties in this study were all trained and pruned to open centre system and no significant differences was observed in tree height. There was no significance differences in trunk girth among the varieties (P = 0.533) (Table 1). The maximum mean value 45.68 cm was observed in *Atago* and minimum of 38.33 cm (n = 3) for *Yakumo*. The trunk girth is affected by the rootstock used (Beutel, 1990). The varieties that were investigated were all grafted on Pyruspashia (locally available in the country) and no significant differences were observed in terms of trunk girth among the varieties. There was significant difference (P = 0.011) among the varieties with respect to tree canopy area (Table 1). The maximum canopy area was recorded in *Shinko* with mean value of 19 m^2 (n =3) which significantly differed from Wengkhar Lhee 1 and *Yakumo*. The minimum canopy area was observed in *Yakumo* with 12 m^2 which was statistically different from all the varieties except Wengkhar Lee 1. The difference might be due to genetic makeup, climate and management aspect such as training and pruning (Honty et al., 2004). The average canopy area

in Wengkhar Lee 1, *Kikusui, Hosui, Yakumo*, and *Shinko* in sandy soil was found to be smaller by 50% than those grown in optimal soil condition as per the findings of Honty et al (2004).

Table1. Mean values of tree height, trunk girth and canopy area

Varieties	Tree height (m)	Trunk girth (cm)	Canopy area (m²)
WengkharLhee 1	3.63a (±0.18)	43.35a (±3.18)	14.72ab (±1.45)
Shinko	3.83a (±0.57)	44.01a (±3.00)	19.12c (±0.68)
Atago	4.03a (±0.40)	45.68a (±1.68)	17.33bc (±1.21)
Hosui	3.73a (±0.18)	41.33a (±3.48)	17.95bc (±0.84)
Yakumo	3.16a (±0.03)	38.33a (±2.84)	11.85a (±0.43)
Kikusui	3.36a (±0.21)	42.66a (±1.45)	16.09bc (±1.79)
S.E.D	0.130	1.087	0.702
P - value	0.474	0.533	0.011

Note: Values with same alphabetical letter within column denotes no significant difference among the varieties at P = 0.05. The values in the parenthesis are standard errors of means

3.2 Leaf characteristics

The highest leaf length was observed in *Shinko* with mean value of 12.07 cm (n = 30) but not statistically different from the mean length of *Atago* and *Hosui*. *Atago* has the maximum mean leaf width of 7.50 cm which is statistically different from all other varieties. *Hosui* had the maximum leaf blade ratio of 1.86 (n = 30) which is significantly different from rest of the varieties (Table 2). The present study revealed long and

Table 2. Morphological characters of leaves

Varieties	Leaf length (cm)	Leaf width (cm)	Leaf blade ratio
Wengkhar Lhee 1	11.25ab (±0.14)	6.97c (±0.10)	0.23b (±0.008)
Shinko	12.07c (±0.14)	6.63b (±0.08)	0.18a (±0.007)
Atago	11.69bc (±0.19)	7.50d (±0.08)	0.21ab (±0.010)
Hosui	11.71bc (±0.17)	6.32a (±0.10)	1.86d (±0.026)
Yakumo	11.33ab (±0.15)	7.06c (±0.10)	0.23b (±0.007)
Kikusui	11.03a (±0.22)	6.57ab (±0.10)	0.42c (±0.011)
S.E.D	0.075	0.048	0.045
P -value	<0.001	<0.001	<0.001

Note: Values with same alphabetical letter within column denotes no significant difference among the varieties at P = 0.05 and 0.01. The values in the parenthesis are standard errors of means

broad leaves for all the varieties that do not signify leaf length as short, medium, long, and leaf width as narrow, medium and broad respectively as in characters suggested by UPOV (1994) for distinctness uniformity and stability for inclusion in descriptor Lists for *Pyrus pyrifolia*. It might be due to sampling numbers in the present study that fail to capture the differences. However, result in leaf blade ratio is comparable to the study conducted by Singh et al., (1999).The leaf blade ratio indicates the size of the leaves for the given variety. The size of leaf is an important character used for variety identification.

3.3 Fruit characteristics

There was highly significant differences among varieties with respect to the fruit weight (P = 0.001). The maximum mean fruit weight was observed in *Atago* with 682.50g (n = 30) and a minimum of 229.17g for *Kikusui* (Figure 1). The fruit weight in *Hosui* (250 g), *Shinko* (224 g), *Niitaka* (352 g) and *Atago* (359 g) were observed in ten years old trees in Carolina by Reighard et al., (2008).

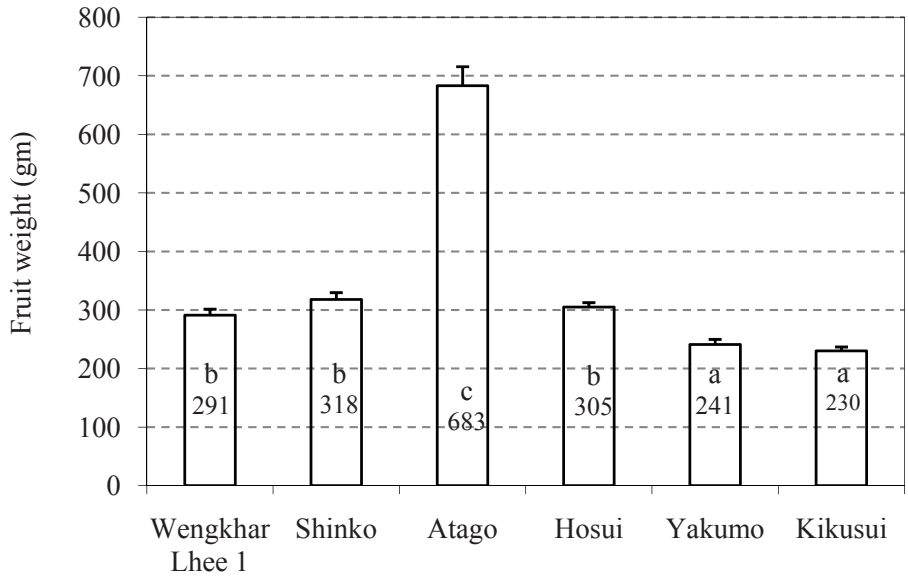

Figure 1. Mean fruit weight of Asian pear varieties

The fruit length and fruit diameter constitute the size of the fruit. There was highly significant differences among the varieties on fruit length

and width (P = 0.001). The maximum mean fruit length and width were observed in *Atago* with mean of 94.44 cm (n = 30) and 115.54 cm respectively. The minimum mean length of 69.93 cm and width of 80.68 cm were observed in *Kikusui* (Table 3).

Table 3. Mean fruit length and width, fruit shape index

Varieties	Fruit length (cm)	Fruit width (cm)	Fruit shape index
WengkharLhee 1	73.03a (±1.09)	86.26bc (±1.97)	0.87
Atago	94.44c (±1.49)	115.54d (±3.70)	1.22
Hosui	78.04b (±1.11)	87.56c (±0.70)	0.9
Yakumo	69.99a (±0.94)	81.13a (±0.95)	0.86
Kikusui	69.93a (±0.79)	80.68ab (±0.77)	0.87
S.E.D	0.772	1.155	2.504
P-value	<0.001	<0.001	<0.001

Note: Values with same alphabetical letter within column denotes no significant difference among the varieties at P = 0.05 and 0.01. The values in the parenthesis are standard errors of means

Fruit size is an important factor in determining the market returns. Most domestic and export markets have a preference for large fruit (Bevington, 2003). For instance, large fruits (72 mm) are preferred and smaller fruits (65 mm) are often found hard to sell in the case of citrus. Fruit size can be affected by wide range of variables such as variety, tree health, nutrition and irrigation, orchard management and environmental factors. Highly significant difference was observed among the varieties on fruit shape index (P = 0.001). The maximum mean shape index of 122.3% was observed in *Atago* and minimum of 86.4 % in *Yakumo* (n = 30). The fruit shape index determines the shape of fruit. The value 1 indicates round and value near to 1 indicates almost round while far above and below 1 indicates oblate or oval (UPOV, 1994). The TSS (%) indicates the sweetness of the fruit. This is one of the important quality parameters for most of the fruit crops. There was highly significant differences among the varieties with respect to TSS (P = 0.001). The highest mean TSS was observed in *Hosui* with 12.61% (n = 30) but was not significantly different from *Atago* and *Wengkhar Lhee 1* (Figure 2). The lowest TSS was observed in Shinko with 9.69% (n = 30) which is significantly different from the rest.

The variability in TSS among six varieties could be due to varietal characters (Wang, 1982). The variety that mature during plenty of rain showed less TSS compared to those mature in sunny dry weather in pears

(Wang, 1982). The variation in TSS among varieties might also be due to plant nutrients availability, soil condition, fruit bearing position and climatic condition (Hudina and Stampar, 2000). High nitrogen level and sandy soil also lower TSS in fruit.

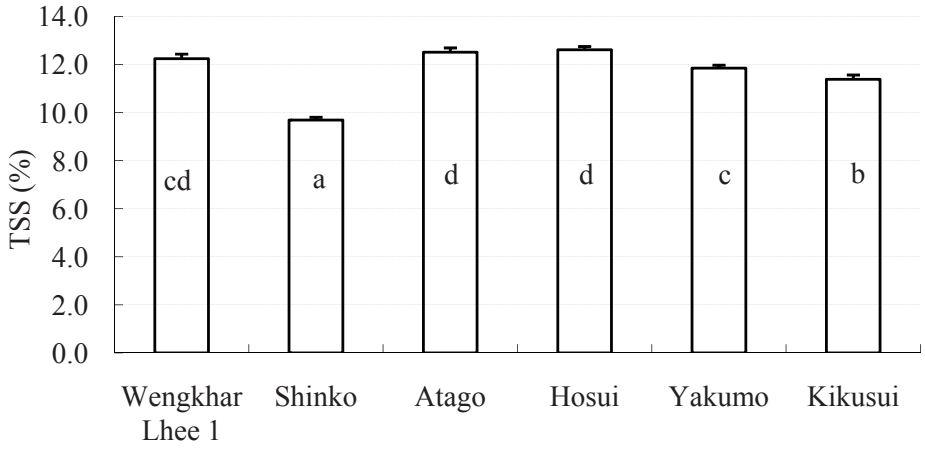

Figure 2. TSS (%) content of fruits for different varieties (Values with same alphabetical letter within column denotes no significant difference among the varieties at P = 0.05)

The study shows that *Wengkhar Lhee* 1 possess maximum firmness with a mean of 3.84 kg/cm² (n = 30) which is significantly different from of rest of the varieties. The lowest firmness was observed in *Hosui* (Figure 3). In Asian pear fruit firmness is not a good indicator of maturity (Crassweller, 2006). However the firmness reading of 4 – 5 kg/cm^2 could be considered during harvesting.

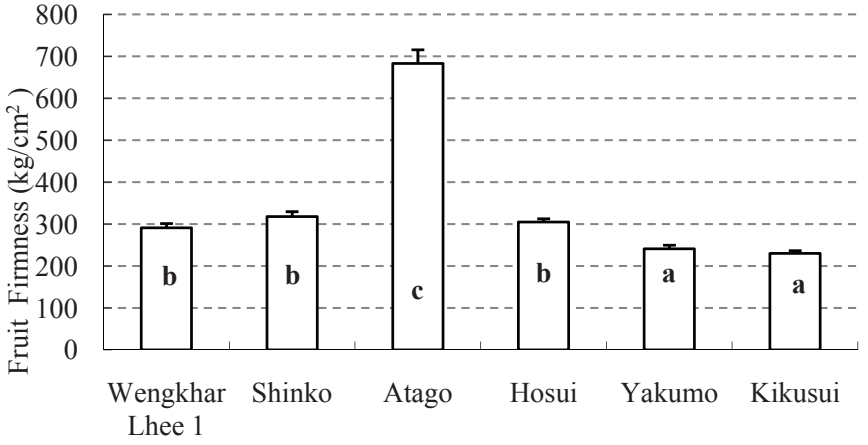

Figure 3. Mean fruit firmness in six Asian pears (Values with same alphabetical letter within column denotes no significant difference among the varieties at P = 0.05)

3.4 Yield and production

The total yield per tree provides information on the production potential under uniform management and environmental condition and age of the trees (Figure 4). The harvest was further graded into marketable and non-marketable yield per tree to know the quality of fruits produced by each of the varieties.

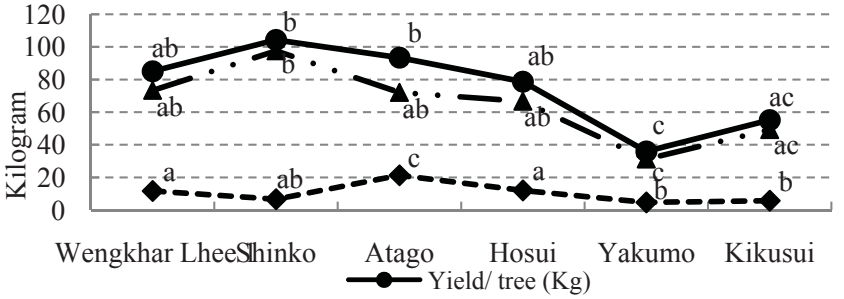

Figure 4. Yield parameters of Asian pear varieties (Values with same alphabetical letter within column denotes no significant difference among the varieties at P = 0.05)

Statistically significant differences among the varieties with respect to yield per tree ($P = 0.004$), marketable yield per tree ($P = 0.008$) and non-marketable yield/tree ($P = 0.001$) was observed.

The highest mean yield was observed in *Shinko* with 104.27 kg and lowest in *Yakumo* with 35.93 kg. However, the mean yield of *Shinko* was not significantly different from that of *Wengkhar Lhee 1, Atago* and *Hosui*. The mean yield of *Yakumo* differed significantly from rest of the varieties except with *Kikusui* (Figure 6). These findings are in conformity with other studies conducted by Reighard et al., (2008). The yield records of 27 kg/tree were assessed in Hungary for Asian pear like *Yakumo*, *WengkharLhee 1 (Chojuro), Shinko, Hosui* and *Kikusui* from nine years old tree (Honty et al., 2004). While in Bulgaria, Tabakov et al., (2002) investigation on reproductive behaviour on Asian pear indicated that *Yakumo* variety exhibited higher yield than *Hosui* and rest of the varieties. Crop load of 200-400 fruits per tree are common on eight to ten years old Asian pear trees (Beutel, 1990). In Japan 500-700 fruits (170-200 kg) are recommended on a large bearing tree. The yield is also affected by the climatic condition such as chilling requirement. Powell (1999) reported that 8-9 year old tress produce an average yield of 70 to 80 kilograms. The maximum marketable mean yield of 97.6 kg (n = 3) was found in *Shinko* and minimum of 31.27 kg (n = 3) in *Yakumo*. The mean marketable yield of *Shinko* was not significantly different from rest of the varieties except *Yakumo* and the mean marketable yield of *Yakumo* was significantly different from all other varieties (Figure 4). *Hosui* matures early among the varieties, while *Yakumo, Wengkhar Lee 1, Kikusui* and *Shinko* are mid varieties and *Atago* is late. Proportion of non-marketable fruits was observed in the range of 7-23% with minimum of 6.67 kg (n=3) in *Shinko* and maximum of 21.3 kg (n=3) in *Atago.* This may be due to soft nature of Asian pear as described by Powell et al., (1999).

4. Conclusion

Significant variation and similarities were observed in terms of morphological characters among the six Asian pear varieties. *Shinko* is more vigorous compared to *Yakumo* and *Wengkhar Lee 1* in canopy area while rests were similar. *Wengkhar Lee 1*, *Yakumo* and *Kikusui* exhibited similar leaf characters while *Hosui, Shinko* and *Atago* are alike. *Hosui* had comparatively less leaf width and high leaf blade ratio than rest of the varieties. In fruit characters, *Shinko* had highest yield record but low TSS and medium firmness. *Atago* and *Wengkhar Lee 1* had high TSS compared to *Hosui, Yakumo* and *Kikusui.* The *WengkharLhee 1* possessed comparatively better firmness indicating that it can resist transportation damages better. The fruit size varied from large to medium with *Atago*

(94.44cm, 115.54cm) and *Shinko* (79.71cm, 89.02cm) possessing the largest fruit size and shape ranged from oval to oblate. The production potential of the tested varieties like *Kikusui* (36-104kgs/tree) has been found to be at par or much better than say in Hungary (27 kg/tree) and Japan (70 kg/tree) on their eight years old trees. The study revealed a large variation in the morphological characteristics of six Asian pears. The variation itself provides a subject for further studies. The current study could not include the morphological study of flowers which remains to be studied.

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Effects of different herbicides on Shochum in Paddy

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Abstract

Potamogeton distinctus locally known as 'Shochum is a serious weed of rice in Bhutan. Its severity increases because of extensive use of Butachlor that eliminates other weeds that otherwise compete with shochum for nutrients coupled with inappropriate timing of hand weeding practice. Hand weeding is labour intensive and relatively ineffective. Hence this study examines options in order to manage this noxious aquatic weed. Herbicides such as Ethoxysulfuron 15% WDG (Sunrice) and Oxadiargyl 80% WP (Topstar) were claimed to be effective against shochum and were introduced in Bhutan through Bayer Crop Science. The study was conducted on-station at RDC Bajo with four treatments with three replications. The study showed higher grain yield and lower shochum biomass weight from the plots treated with Sunrice. The highest grain yield of 2600 kg/acre from on-station and 3990 kg/acre from on-farm was obtained from the plots treated with Sunrice. Similarly, the highest fresh weight of shochum biomass was 2512 kg/acre recorded from the control plot from on-station trial and 2324 kg/acre from farmer practice plot on-farm. The results also show an increase in Shochum biomass after the 4th week of transplanting indicating the period between 20 to 30 days from transplanting as the critical period in rice-shochum association.

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Keywords: Rice; Shochum; Labour; Weed Management; Production

1. Introduction

Potamogeton distinctus belonging to the family Potamogetonaceae, (local name *shochum)* is considered to be the most serious rice weed in Bhutan. It is a perennial, floating-leaved aquatic plant with rhizomes down to 20 cm in the soil below, which form dormant resting organs (rhizome tips or turions) at the end of the season and emerge as soon as flooding recurs the following season. *Potamogeton distinctus* is an aquatic weed with excellent adaptation to dry seasons and to cultivation. It does this by having an efficient means of survival from season to season in the form of dormant rhizome tips buried deep in the soil. These sprout and develop very rapidly

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as flooding resumes, as in irrigated rice crops. This is the most serious weed of rice in Bhutan which if not controlled can reduce rice yield as high as 37% (CARD, 1988-1992). The weed spreads rapidly, propagating from any living plant part, and the underground parts easily overwinter and grow back in the following year. It also spreads through irrigation water. Farmers normally carry out two to three hand weedings but this practice does not ensure complete removal of weeds from their fields mainly because of the inappropriate timing of weeding (usually late). The use of the herbicide butachlor to control grasses and sedges, as is widely practiced by farmers, eliminates weed competition and allows shochum to proliferate. Chemical herbicides like SANBIRD and NC 311 were proven to be effective (Nidup et al., 2000) but are very expensive. Traditional method of hand weeding is labour intensive and relatively ineffective. The problem of 'Shochum' in transplanted rice is on the increase with farm labour shortage as the nationwide problem, labour requirement for weed management in rice is the major production constraint. Hence there is an urgent need to look for all available options in order to manage this noxious aquatic weed.

Herbicides such as Sunrice (*Ethoxysulfuron*) and Topstar (Oxadiargyl) were introduced to Bhutan through Bayer Crop Science Limited based in Kolkata, India. During his visit to Bhutan, Dr. Bhat agreed to send some of his company products for testing under Bhutanese agro-ecological condition. Plant protection chemicals were received by RDC Bajo, which included two weedicides viz. Ethoxysulfuron 15% WDG (Sunrice) and Oxadiargyl 80% WP (Topstar). These weedicides were said to be effective in controlling shochum. Numerous reports, both success and failure, had been reported on shochum weed control in rice production both within and abroad. Thus this trial was planned and carried out on-station with the aim to validate the efficacy of the above mentioned chemicals in controlling the noxious rice weed.

Ethoxysulfuron a.i 15.00% w/w and other ingredients include 85.00% w/w. It is said to be very effective sulfonylurea early post emergence herbicide used in transplanted rice against broad-leaved weeds. It was initially developed by Hoechst AG and later further developed by AgrEvo GmbH. It is a light beige granule with slightly sweet odour.

It is said to rapidly metabolize in rice plants with occurrence of some minor metabolites; only one metabolite was identified as major. The uptake of radioactivity from the soil is mentioned to be very low. In rice

most of the total radioactive residue is said to be consisted of Hoe 095404 which is mainly degraded by micro-organisms in soil. Under paddy field conditions the degradation is believed to be moderate but there is no risk of persistence or accumulation in soil for Hoe095404. Leaching into the groundwater is stated unlikely and the product residues are confirmed to be fixed in the upper soil layers which are decomposed by micro-organisms. Similarly it is classified as non-toxic to earthworms after LC50 earthworm studies were conducted using artificial soil and the compost worm *Eisenia foetida:* 14 day LC50>1000mg/kg soil. Furthermore, investigations were conducted with Ethoxysulfuron at a concentration of 400 times the recommended rate, showing negligible to tolerable effects on soil respiration, nitrification and ammonification.

It is mainly taken up by the leaves and is translocated within the plant inhibiting acetolactate synthetase. After the inhibition of plant growth, chlorotic patches develop and spread acropetally and then basipetally. The action of the product reaches its conclusion about 3 to 4 weeks after the application resulting in the death of whole plant. It is supposed to be very good in controlling the broad-leaved weeds and water fern sedges. It is a pre to post emergence herbicides to be used in rice, cereals and sugarcane. The excellent tolerance of the crops to the product allows extended application period from 1-2 leaf stage of the crop until late booting.

Oxadiargyl a.i 80% m/m, adjuvants 20% m/m is a white colored powder herbicide with activity on shoots. The efficacy would be obliterated by any soil preparation, even superficial so that no damage could be expected for a succeeding crop. This was confirmed by a rotational crop study where the residues in crop planted 1.4 and 12 after application of oxadiargyl had very low residue levels.

The metabolism of oxadiargyl has been investigated in a number of crop species, including sugarcane, tomatoes, rice, lemons, potatoes and sunflowers. The metabolic route is said to be the same in all plant species. There is limited uptake of oxadiargyl from the soil and very limited translocation within the plants. Oxadiargyl is a major component of the total radioactive residue in all plant species, a number of metabolites were also mentioned to be found although the extent of metabolism is limited. The principal components were the same in all the plant species indicating that the metabolic pathway was not dependent on the plant species. The results obtained to date clearly indicate that the level of residues at harvest always

is below the quantification limit of the method (generally 0.01mg/kg,0.05 mg/kg for studies conducted in Brazil). In addition, it was shown to be practically non-toxic to earthworms with negligible effects on the activity of soil microflora even when applied at 5 fold the field rate.

It should be uniformly applied to the soil surface in order to form a homogeneous herbicide layer as its effect on weed begins at germination when new shoots come into contact with soil particles coated with oxadiargyl. Growth of the weeds is stopped when they grow through this soil as tissue become necrotic, resulting in the death of weed seedlings. Literatures also demonstrated that oxadiargyl acts by contact with the plant tissue as there was limited uptake and virtually no translocation in the plant. Application should be done 2-3 days before transplanting or 3 days after transplanting but not later than two-leaf stage of the weeds because it binds firmly to the soil and it doesn't affect the roots. It works only on the shoot.

2. Material and Method

2.1 Study area

The trial was conducted on-station at RDC Bajo for three consecutive years (2012 – 2012). The trial was laid out in a randomized complete block design (RCBD) with three replications. Good quality seed of rice variety IR 64 was used and rice seedlings were transplanted in 25 sqm plots at a spacing of 20 x 20 cm. Chemical fertilizers was applied as per the recommended rate (70:40:40 NPK kg/ha) with all of the P and K fertilizers with half the N as basal dressing and the other half N as top dressing at tillering stage. FYM was applied at the rate of 7.5 t/ha. To control the weed, weedicides were applied as per the treatments. Proper crop management, including pest control was applied as and when required. Similarly hand weeding was done at the tillering stage and irrigation was applied as and when required. Treatments were; T1 – Topstar (45 gm/acre), T2 – Sunrice (40 gm/acre), T3 – Butachlor (12 kg/acre) and
T4 – Control.

Topstar was applied immediately after rice transplantation at the rate of 45 gm/acre. The weighted chemical was first made into paste and then mixed with 20 – 25 kg of sand for broadcasting. Similarly, sunrice was applied 10 days after transplanting at the rate of 40 gm/acre. The treatment plots were drained out and kept the soil just moist for spraying the solution.

The plots were flooded after 24 hours. Butachlor was broadcasted 3-4 days after transplanting at 10-12kg/ acre. Weed samples were collected from each treatment plot at 20 and 40 DAT using 0.5x0.5m quadrate. Weeds were segregated into shochum and others for weighing and data recording. At maturity, grain yield was estimated from a harvest area of 6 sqm and grain moisture content was standardized at 14%. Data generated was analyzed using ANOVA.

3. Result and Discussion

Table 1 shows the rice grain yield difference between the treatments during the last three years. The effect of different treatments on the rice grain yield was significant at 5% significance level. The plots treated with Sunrice and Topstar yielded significantly higher than Butachlor treated one indicating the ineffectiveness of Butachlor in controlling shochum.

Table 1. Effect of the treatments on the grain yield

Treatments	Grain Yield (Kg/Acre)		
	2010	2011	2012
Topstar	2104	2293	1962
Sunrice	2318	2600	2317
Butacholor	1506	2160	1541
Control	1384	1546	1186
P value	0.002	0.041	0.000

Table 2 presents the different weights of fresh shochum weed biomass between the treatments. Fresh shochum weed biomass weight was significantly less from the plots treated with Sunrice and the results were consistent during the last three years with lowest weight recorded for the year 2012. The highest fresh weight of shochum weed biomass was recorded from the plots treated with Butachlor and the control. The results indicated that there is an inverse correlation between rice grain yield and shochum weed biomass.

Table 2. Effect of the treatments on fresh weight of Shochum weed biomass

Treatments	Fresh weight of shochum (Kg/Acre)		
	2010	2011	2012
Topstar	520	810	731
Sunrice	238	170	75
Butacholor	2008	878	1047
Control	2164	1346	2512
P value	0.000	0.207	0.005

Table 3 shows the different weights of other weed biomass between the treatments. Fresh weight of other weed biomass was recorded lowest from the plots treated with Butachlor followed by Topstar. While application of Butachlor in transplanted rice is said to eliminate almost all grasses and sedges, Topstar seems to have effect both on shochum and on other weeds, though not as effective as Sunrice against shochum control and Butachlor for other weeds control. The variation in the weights of the weeds across the years could be because of the changes in weed intensity and population over the period.

Table 3. Effect of the treatments on fresh weight of other rice weed biomass

Treatment	Fresh weight of other weeds (Kg/Acre)		
	2010	2011	2012
Topstar	144	46	350
Sunrice	518	138	1186
Butacholor	43	82	141
Control	822	1070	3100
P value	0.01	0.07	0.025

Based on the results of the on-station trials, the herbicides were tested for their effectiveness against shochum at Lobesa with three selected farmers. The severity of shochum weed appears to be increasing especially in Lobesa area mainly because of extensive use of Butachlor by farmers that eliminates other weeds that otherwise competes with shochum for nutrients, space and sunlight and fewer hand weeding practice of the farmers in the valley. Figure 1 shows the results of the on-farm trial. With $p=0.05$, the effect of different treatments on the weight of fresh shochum weed biomass both at 20 days and 40 days after rice transplantation was significant at 5% significance level. Results indicated a sharp increase in weed weight after the 4^{th} week of transplanting, which affected the ability of the rice plant to produce tillers/panicles. Furthermore, the results both from the on-station and on-farm trials showed that the critical period in rice-shochum association is between 20 to 30 days from transplanting.

However, the results of the on-farm trial did not show significant effect of treatments on the yield component at 5% significance level. The highest grain yield of 3990 kg/acre was obtained from the plots treated with Sunrice and the lowest grain yield of 3850 kg/acre was attained from farmer practice (application of Butachlor with one hand weeding) plots. Even with little difference in the grain yield between the treatments, many farmers

expressed their interest in using the herbicides as they have seen the treated plots without shochum during the farmer field day.

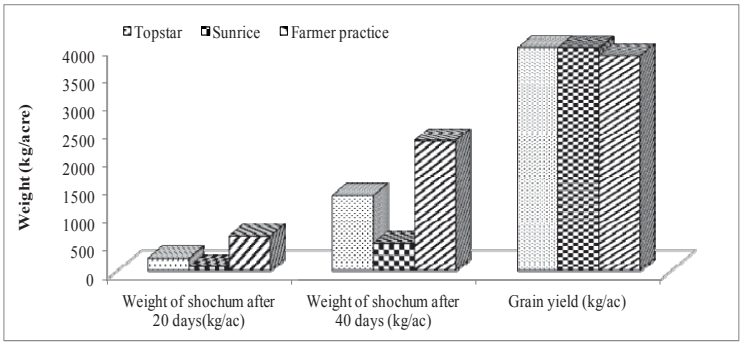

Figure 1. Fresh shochum weight and rice grain yield by treatments

Labour shortage being the main constraint in rice cultivation, most farmers stated that the use of these herbicides could be an option for them to address the labour problem and increase rice production. It has become clear that there is no shortage of lessons to be learned in shochum weed management in rice and there are opportunities for effective control. If a given technology helps farmers to garner robust profits, it will spread quickly. Farmers make decisions on how to maximize profit and minimize risk and this decision making happens for a whole sequence of crop management operations. The findings have given researchers and extension workers hope for increasing rice productivity through shochum weed management.

4. Conclusion

This study conducted over a period of three years clearly showed the effect of the different herbicides on shochum weed biomass and rice grain yield. The effect of different treatments on the rice grain yield was significant. The plots treated with Sunrice and Topstar yielded significantly higher than Butachlor treated one indicating the ineffectiveness of Butachlor against shochum. Fresh shochum weed biomass weight was significantly less from the plots treated with Sunrice for last three consecutive years. The results indicated that there is an inverse correlation between rice grain yield and weight of shochum biomass. Results indicated a sharp increase in shochum biomass after the 4^{th} week of transplanting, which might have affected the ability of the rice plant to produce

tillers/panicles resulting in lower yields. Furthermore, the results both from the on-station and on-farm trials showed that the critical period in rice-shochum association is between 20 to 30 days from transplanting.

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Effect of Effective Micro Organisms on Small Composts in School Agriculture Garden

Bal Bahadur Rai[11]

Abstract

This paper describes the materials required, steps of compost making and the effect of using Effective Micro-Organisms (EM) solution as inoculants in compost making in school agriculture garden. The findings and results are the out come from a replication of two treatments one with the use of EM as inoculants and other without the use of EM solution. At the end of the 3 months study, the result shows the positive aspects of using EM as inoculants in composting using local materials as biomass. The use of EM has reduced the decomposition time by two weeks while maintaining the higher nutrient contents compared to control plot.

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*Keywords***:** Effective Micro-Organisms; inoculants; decomposition; organic farming, activated EM, C:N ratio

1. Introduction

Bhutan has enormous potential for organic products and marketing of niche products. Despite the government support to supply free EM stock solution to farmers for encouraging organic farming it has been a lukewarm progress of EM usages in Bhutanese farming although EM was introduced in early 2005 by Ministry of Agriculture. (MoA, 2006). Among many technologies of organic farming, compost making is one of the easiest methods our farmers can adopt. However, the traditional method of compost making takes a long duration of about 10-12 months (CoRRB, 2004). In the recent years, the Ministry has been promoting heap composting methods, which takes relatively shorter duration for decomposition in comparison to pit composting method (DoA, (2005).

Composts are one way to promote organic farming which can dramatically substitute the use of synthetic fertilizers and chemicals. The use of organic manures viz; compost, farm yard manures (FYM) and top soils is very important in organic farming. However, there was a need to

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develop a technology which can decompose the organic materials at a faster rate with intact nutrient contents. EM (Effective micro organisms) is the mixture of locally available beneficial microbes' cultures and isolated from the natural ecosystem in liquid form to be used as inoculants. Application of activated EM, hastens the process of decomposition rate (DoA, 2007). The study was done to accelerate the decomposition rate of compost in Bhutanese condition. So that farmers can make as many composts with the abundant biomass during the weeding season and use them immediately for the winter crops.

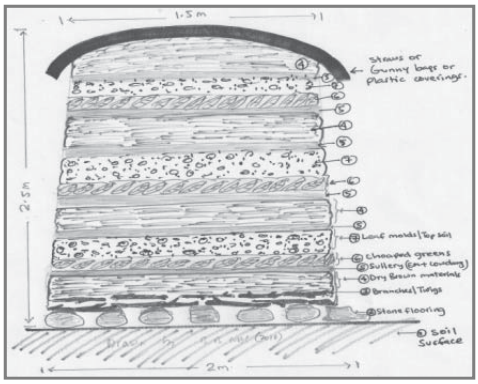


Fig1: Compost heap piling

2. Materials and Method

The study was carried out in two treatments, two replications for the treated and one replication for the control. The treatments were compost using locally available raw materials with EM as activator as one treatment and the control plot with equal amount of same materials used in treatment block but without using EM as inoculants/activator.

Table 1. Particulars of EM compost and layers

Particular	Quantity
Hay (Paddy straw)	1 tractor load
Cow dung/FYM	½ tractor load
Green/dry grasses	½ tractor load
Top soil	1 Hilux load
Activated EM solution	5 litres
Gunny bags	15 Nos
Stones/bricks	30 Nos
Wood branches	3 bundles
Sugar/Guar/Molasses	1 Kg

The replications were placed at three different locations under same conditions. The temperature built inside the heap was measured at regular interval of 10 days in each heaps and the rate of decomposition was recorded. The higher the temperature recorded, faster the decomposition of organic matters observed (WEPCO, 2007).

2.1 Heap site and size

The site was selected in the compost shed of CNR as the ideal condition for compost heap should not be in water logged areas. It should be either under a semi shed or under a canopy of well branched trees. Compost do not like too much of rain or too much of sunshine. Ideally it should be a forest condition with optimum moisture and light (CoRRB, 2004). The size of heap should not be too big or too small. If the heap is too big, it is difficult to handle and there will be some portion without moisture and heat do not build up. Similarly, if the heap is too small, it will easily dry up very soon and the temperature will be difficult to build up (DoA, 2007). Therefore, the heap was made of 1.5 m length x 1.5 m breadth x 1.5 m height, with tapering top narrower than the base, (Figure1).

2.2 Preparation of EM solution

EM mother stock solution was fetched from NSSC, Simtokha and activated at CNR Lobeysa for further dilution and used as solution mixed with cow dung slurry in different layers of heap compost. The EM mother solution was activated by mixing with sugar/molasses at ratio of 1:1:100 (EM: Molasses: Water) and fermented for a week, after which it was ready for use (Higa T, 2009). This diluted EM solution was mixed in cow dung slurry at ratio of 1:10 (Diluted EM : Fresh cow dung solution), which was sprinkled at every layer of heap compost as inoculants for the treated blocks (http/www.apnan.org).

2.3 Formation of compost heap

The formation of heap is like making the foundation of a building and mixing of different materials of green and brown materials similar to making a good dish for ourselves (MoA, 2003). The foundation of heap was made with thinly laid stones/bricks and on top of stones tree twigs and branches were kept for good aeration and strong basement. The first layer of heap on top of the twigs was brown materials viz (chopped straws) followed by green materials and leaf litters/top soil. In every layer, water was sprayed to make the materials well drenched followed by spreading of cow dung slurry mixed with activated EM.

The process was repeated in a similar method after the third layer until the desired height of 1.5m was obtained. Each layer of brown materials was maintained to 45 cm thickness and green materials (2-5 cm)

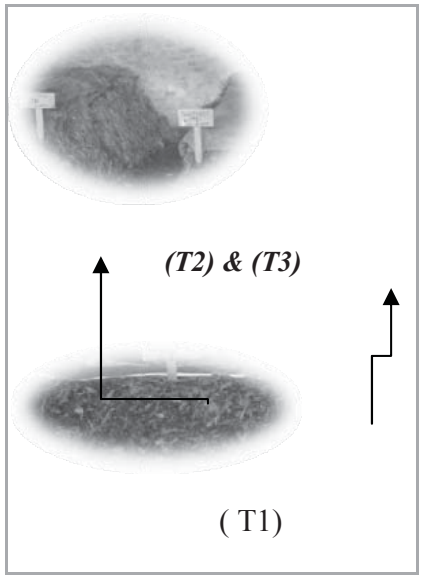
thick of chopped green materials, to maintain the carbon to nitrogen (C: N) ratio of 25:1. Carbons are required by microbes as food. The heap was covered with gunny bags to retain heat and moisture.

Figure 2. Layout and design of the experiment

Two treatments were made, where two heaps were treated with EM and one heap was control, without EM application. T1 was control without application of EM, T2 and T3 were treated with EM (Figure 2). The heap composts were prepared under the compost shed of CNR farm. All the heaps were made with same composting materials with equal proportions.

2.4 Management

Every 10 days, the temperature and the rate of decomposition were recorded. A mercury thermometer and radiator device was used to measure the heat development inside the compost. The faster the heat formation, more the microbial activity resulting faster decomposition rate of compost (WEPCO, 2007). The population of microbes are influenced by the available or balance of C:N ratio preferably to 25-30:1.



The decomposition rate was manually determined by its textures taken out from the inner portion of heap. The basis of decomposition was 0% at the time of heap

formation and the product at the harvest time was 85% decomposed. The heap was turned over after every four weeks making a total of two turnings and mixing up. Sufficient moisture in the heap compost was monitored by sprinkling water during the heap turnover operation.

3. Result and Discussion

At the end of 9th week, 3 composite samples from each heaps were taken out for nutrient analysis. From each heap 3 samples representing the top, middle and bottom were collected. A total of 9 samples were sent to Soil and Plant Analytical Laboratory (SPAL), National Soil Services Centre (NSSC) for analysis. The record of temperatures and decomposition rate were collected at an interval of 10 days as presented below in table 1. The rate of decomposition was observed at faster rate with the increase in temperatures. The compost heaps with the use of activated EM has shown faster increase of heap temperature compared to the control heap. The compost with EM as inoculants has added the microbes population and the multiplication of microbes are faster in the treatment block, which generates the heat resulting faster decomposition rate. Figure 2. Treatments in the compost

However, after 4 weeks the temperatures falls down even with optimum temperatures and moistures (Figure 2). This is basically the food supply gets exhausted and the microbial activities decreases. Therefore, this is the stage compost need turning over and mixing the undecomposed materials which adds food and provides air for another cycle of microbial activity. The compost has been moistened with sprinkled water to maintain the optimum moisture contents but without making the condition water logged. There will be less microbial activities in a water logged condition due to lack of oxygen for microbes (NSSC, 2007).

From the below data obtained from two months study, it has been provisionally concluded that compost making with the use of activated EM can reduce the decomposition process by three weeks (30% earlier) compared to composting without any inoculants. Therefore, farmers can make more amount of compost within a season, when lots of bio mass is available. The rate of temperature increased in first three weeks very rapidly

Table 2. Temperatures and decomposition rate of compost

Date	T1		T2		T3		Remarks
	Temp (°C)	Decomposition (%)	Temp (°C)	Decomposition (%)	Temp (°C)	Decomposition (%)	
19/3/2010	25	0	25	0	25	0	Compost
28/3/2010	49	15	53	20	57	20	
6/4/2010	50	25	58	35	63	35	
16/4/2010	46	30	48	46	58	45	1st mix
26/4/2010	48	35	53	50	56	55	
6/5/2010	50	40	62	65	65	70	
16/5/2010	46	50	55	75	50	80	2nd mix
26/5/2010	46	55	56	80	50	85	

reaching to 63°C and the after that it gradually decreased. But the rise of temperature again increases after the turning over of the heap as indicated in (Figure 3). The increase of temperature is due to high microbial activity in the compost heap and decrease in temperature as the food gets exhausted Ghosh N and Das AK (2008).

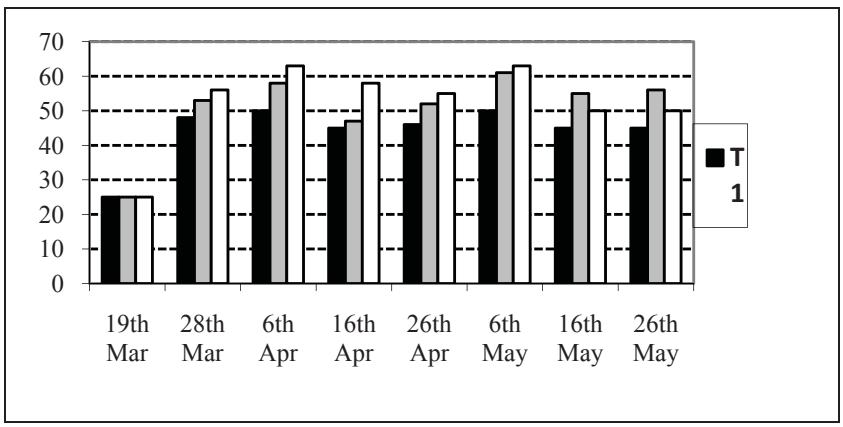


Figure 3. Temperatures generated in the three different compost treatments

Table 3. Laboratory result of compost analysis

Replication	N %	P %	K %	Na %	Ca %	Mg %
T1 (Top)	1.03	0.16	1.67	0.09	2.82	0.25
T1 (Mid)	1.04	0.34	2.94	0.16	3.94	0.41
T1 (Bottom)	1.10	0.23	1.83	0.12	2.95	0.42
Mean	1.05	0.24	2.14	0.12	3.23	0.36
T2 (Top)	1.25	0.38	2.63	0.16	2.87	0.37
T2 (Mid)	1.63	0.39	2.98	0.17	3.65	0.42
T2 (Bottom)	1.57	0.26	3.14	0.20	4.09	0.37
Mean	1.40	0.34	2.91	0.17	3.54	0.38
T3 (Top)	1.66	0.26	1.29	0.15	3.74	0.40
T3 (Mid)	1.57	0.28	2.68	0.17	3.66	0.45
T3 (Bottom)	1.41	0.27	2.60	0.14	3.47	0.43
Mean	1.54	0.27	2.11	0.15	3.62	0.42

4. Conclusion

The provisional results have clearly indicated the positive aspects of EM solution, which has hastened the decomposition process by 20 days. The study showed that it takes 2 months to obtain 80-90% decomposition in EM treated heap compost and the same compost would decompose only 50-60% without the use of EM. Therefore, the study concludes that under same conditions of heap composting the use of EM can enhance the decomposition by 21 days earlier than the composting without the use of EM. The research work carried for the last 2 months on composting with EM has produced 85% of decomposition and 50% decomposition was observed in control plot. The study carried out for the last 3 months using EM in heap compost has shown positive differences in terms of reducing the duration of decomposition rate by 30% and the odourless compost. The nutrient contents viz; N, P, K, Na, Ca and Mg in the EM treated compost are comparatively high. However, with one time study, the results are not conclusive and recommend further studies.

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Impact of Vegetable Promotion through Research Outreach Programme in Drepong, Mongar

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Abstract

Research outreach program aims taking onboard research technologies to farmer's field in order to upscaling the vegetable production in Laptsa and Drepong, Mongar. The vegetable outreach program in these two villages started from 2008 with formation of informal vegetable grower groups with direct support provided by RDC Wengkhar in collaboration with Dzongkhags till 2011. Therefore, to assess the benefits and constraints faced by the farmers (both group members and non-group members) this impact assessment was carried out comparing the results of before and after ROP through field survey and group discussions. Impact on area, production, capacity development of the farmers, access to various inputs, household income and constraints faced were analyzed. The result indicates more than 35% of the respondents having access to improve varieties and 74% of respondents responded that there was increase in the vegetable production. Mean area for vegetable increased by 0.18 acre for Drepong and Laptsa and 0.14 acre for Zunglen after the research outreach program. Mean annual production of vegetables increased by 46%, 75%, 54% at Drepong, Laptsa and Zunglen, respectively. The percentage of respondents who received various trainings on vegetable was up by 21% for Drepong and 27% for Laptsa. Household income increased by 64%, 92% and 71% in Drepong, Laptsa and Zunglen, respectively. However, the major constraints were unavailability of seeds on time, pests & diseases, lack of irrigation, lack of adequate technical knowledge especially on seed production.

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Keywords: Vegetable research outreach program; vegetable grower groups; vegetable area; capacity development; household income; eastern Bhutan

1. Introduction

Research outreach program (ROP) is one of the extension approaches adopted to upscale technology promotion under the initiative of

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RNR RDC Wengkhar. It is aimed at taking the research technologies and on-farm activities beyond the research station to farmer's field in order to encourage farmer's participation, ensure sustainability and sense of ownerships (Dorji, 2006 and Domang, 2012). ROP as an extension approach gained momentum in the implementation of Agriculture Research and Extension Support Project (AREP) in the region and was found to be one of the best approach to disseminate and upscale research technologies to the farmers and extension agents effectively (RNR-RC Wengkhar, 2009; Domang, 2012). The approach focuses on both individual farmer and community-based farming groups based on their interest and potentials for a particular technology. The distinct feature of ROP is that it follows the cyclic pattern i.e. any farming technologies that are disseminated in one geog are moved to another geog the following year (Dorji, 2006; Domang, 2012).

One such program of the centre was promotion of year round vegetable production program in a particular geog or villages. Implementation of the AREP project began in villages like Thridangbi, Phosorong, Themdangbi and Chali from 2004-2008 with the promotion of year round vegetable production. As a follow up or upscaling of the project activity, RDC Wengkhar initiated similar program in Laptsa and Drepong villages under Drepong geog from 2008. Vegetable grower groups were formed in both the villages, materials and technical input supports were provided for implementation of the program for the period of three years, in collaboration with the Geog Agriculture Extension Office. Through this program farmers made considerable progress in vegetable cultivation and are felt to have made an impact on them. Therefore, it was felt necessary to carry out the impact study of the program in order to assess success and failures of the program.

The overall objective of the study was to assess the impact of research outreach program on vegetable production and its benefits to the farming community of the Drepong geog. The specific objectives were: to examine the spread, adoption and effectiveness of the interventions made in villages where the program was implemented as well as in villages nearby and; to assess the outcome of the program on improving their livelihood as a source of income.

2. Materials and Method

The main beneficiaries of the ROP on year round vegetable production program were the vegetable grower group members of Laptsa and Drepong villages of Mongar Dzongkhag. The study was conducted in these two villages and an adjacent village Zunglen under the same geog. Household survey with structured questionnaire and consultation meetings were held with the randomly selected farmers of these three villages, covering 30% of total households in each of the village. 22 farmers from Laptsa, 19 farmers from Zunglen and 17 farmers from Drepong took part in the study. Geographically these three villages were located at 2200 m, 1700 m and 1000 m above sea level.

Since there was no baseline survey carried out before, therefore, data and information on both pre and post ROP were collected. This was also cross checked with available information of the past from the reports compiled during implementation. For uniform measurement units all the local units expressed by the farmers were converted to standard units by using the conversion table provided in Standard Measurement Units Survey of Bhutan circulated by Central Statistical Organization in 2002. The data collected from the respondents were compiled and analyzed by using statistical package SPSS 16 wherein case summaries, crosstabs, frequencies and some of the graphs were computed. Beside this Microsoft Excel 2007 was used for presentation of results in the form of tables, graphs and charts.

2.1 Limitation of the study

Since the farmers rarely keep farm records, reliability and accuracy of data depended on farmer's interpretation and views expressed during the enumeration. We have not included the data on potato even if it is one of the cash crops in the study area since no support has been provided on potato in the program. The sample size among the three villages surveyed are not equal since some of the respondents were absent during the enumeration. Field observations, photographic records from archives of the program and observations of farmers in the vegetable market were used to authenticate the progress made.

3. Result and Discussion

3.1 Major vegetable crops grown

About 14 different types of vegetables are cultivated by the farmers of which five vegetables were considered as major vegetables grown by the respondents in their respective villages. These five major vegetables were selected based on the percentage of respondents ranking on each of the vegetable crops.

Table 1. Five major vegetables grown in each of the village

Village	Vegetable 1	Vegetable 2	Vegetable 3	Vegetable 4	Vegetable 5
Drepong	Cabbage	Chili	Cauliflower	Peas	Beans
Laptsa	Cabbage	Cauliflower	Broccoli	Carrot	Radish
Zunglen	Beans	Radish	Chili	Cabbage	Mustard Green

It was obvious from the result that in Zunglen where ROP was not implemented 65% of the respondents still grow local varieties of vegetables, while >35% of the respondents grow improved varieties of crops in Laptsa and Drepong.

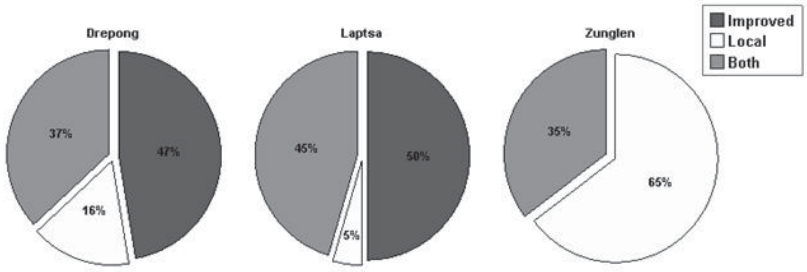

Figure 1. Percentage of respondents on varieties they grow

3.2 Status of the vegetable grower groups

As for the status of vegetable grower groups it was found that the active group members as of now are 8 members in Laptsa, 10 members in Drepong and still there is no vegetable growers group formed in Zunglen (Figure 2). Formation of group from ROP also enabled them to venture into off-

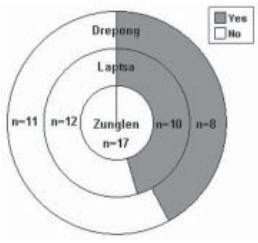

Figure 2. Number of active group members

season vegetable production. Currently these groups have begun commercial vegetable production and one group "*Puengu Gongphel Detshen*" commonly signed an agreement to supply vegetable to Gyelposhing Higher Secondary School (DAMC, 2011). This group with nine members also recently took up establishment of Community Based Sustainable Land Management Village at Laptsa-Shingkhar & Nyamla-Bainangree Tso funded through SLMP-WB/GEF grant, NSSC, DoA as compared to others who have not formed groups (RNR RDC Wengkhar, 2012).

3.3 Vegetable production area before and after ROP

Based on the information provided by the respondents during the survey, the mean total dry land area per household which is feasible for crop production is limited. The total mean area for each of the villages is 1.98 acre (±0.221, n=19), 1.61 acre (±0.238, n=22) and 1.54 acre (±0.257, n=17) for Drepong, Laptsa and Zunglen, respectively. Out of which less than one-third of the total area is used for vegetable production. Since the farmers of these three villages mainly depend on maize and potato maximum area of land is used for these crops. Nevertheless it was observed that there was increase in mean area under vegetable crops after the vegetable ROP was started (+0.18, +0.18 and +0.14 ac increase for Drepong, Laptsa and Zunglen, respectively).

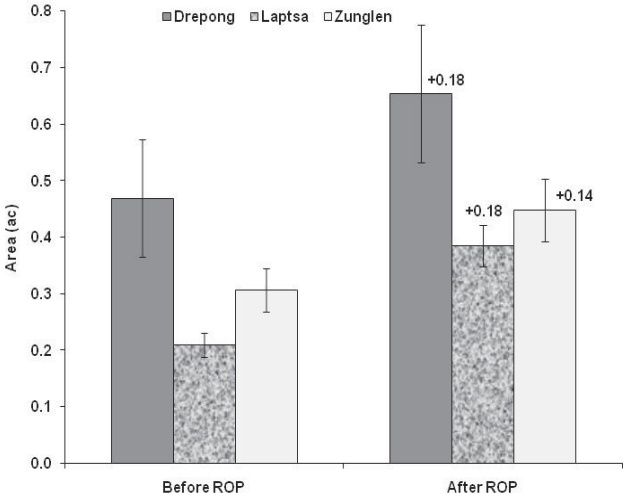

Figure 3. Mean area under vegetable production before and after ROP

3.4 Production trend before and after ROP

The production figures of the five major vegetables grown by the respondents are presented below. The mean annual production of vegetables has been increased rapidly after the ROP was started when compared to that of production before ROP in all the three villages. There was increase in mean annual production by 30%, 60% and 37% after the ROP for Drepong, Laptsa and Zunglen village respectictively (Figure 4). The increase in production may be due to increase in vegetable production area, use of high yielding varieties and improved production technologies after the initiation of vegetable ROP. Despite Zunglen village being not under the vegetable ROP it was observed that there was increase in vegetable production which clearly indicates the counter affect of ROP on nearby village. There was drastic increase in production for Laptsa village (by 60%) which is mainly due to the active group functioning till date on vegetable production.

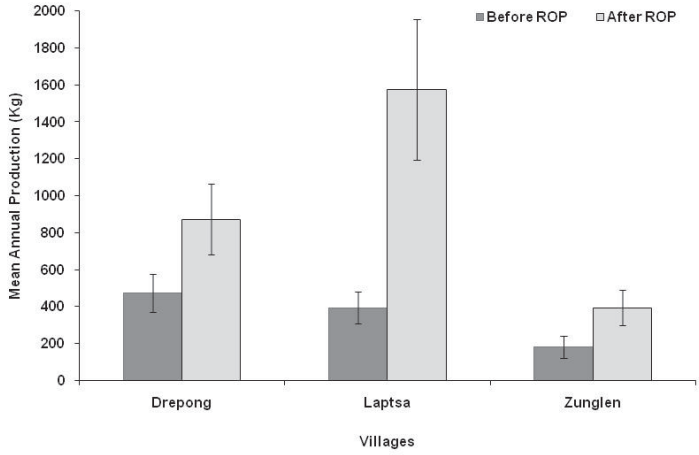

Figure 4. Mean annual production of vegetables

3.5 Input support

The results on whether the respondents received direct input supports in each of the villages indicates that 53% of respondents (n=17) in Drepong and 27% of respondents (n=22) in Laptsa had received the supports before as well as after the vegetable ROP was started. While 53% of respondents (n = 19) in Zunglen had not received any supports.

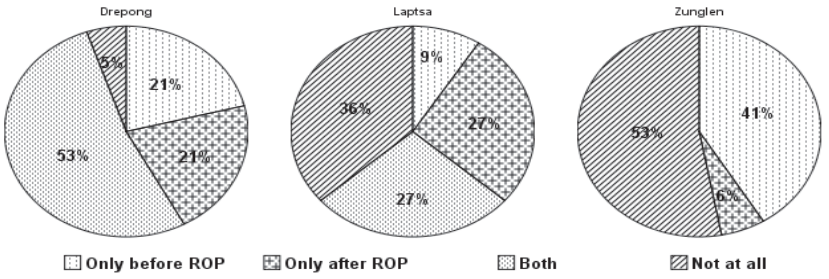

Figure 5. Percentage of respondents on direct inputs support

The main input required for the farmers to venture into commercial or domestic vegetable production is the availability of seeds of high yielding varieties. As for the source of seeds that the respondents depended on before the ROP and after the ROP, the result indicated greater impact of the ROP on the availability of seeds for the farmers. Before vegetable ROP was implemented the main seed source for the farmers of Drepong (84%, n=17) and Laptsa (73%, n=22) was from Dzongkhag. After vegetable ROP was implemented 42% and 54% of respondents of Drepong and Laptsa respectively got seed support from RDC Wengkhar provided with support from AREP-JICA. The result also clearly reflects that the dependence of the farmers on Dzongkhag as a seed source has drastically decreased (decrease 63% and 45% of respondents from Drepong & Laptsa respectively) and increased for other sources. The respondents of Zunglen said that they buy or get in free the seeds from the relatives/friends residing in Laptsa village. Besides seeds and technical support, other inputs such as polyhouses, irrigation pipes, chemicals, tools and implements, water harvesting structures, etc were provided by RDC Wengkhar and Dzongkhag especially for the vegetable grower groups of Laptsa and Drepong.

3.6 Impact on capacity development

As per the concept of ROP, it is aimed to take research technologies beyond the research station to the clients. Research technologies generated from the research centres most of the time are of new technologies or improved techniques, therefore, farmers need adequate capacity building in order to take up or upscale or adopt the new technologies.

The household survey results indicate that there was significant increase in percentage of respondents (increase by 21% and 27% for Drepong and Laptsa villages respectively) who had attended the training after ROP was implemented when compared to that of before ROP (Figure

6). The respondents from Zunglen village reported that they had never attended any training on vegetable.

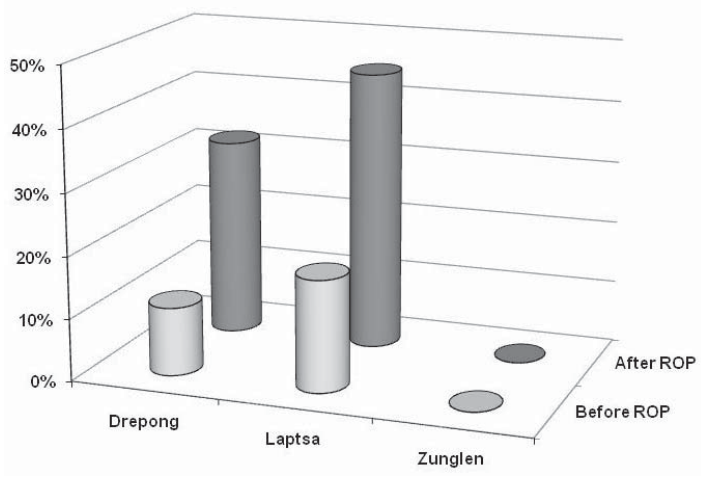

Figure 6. Percent respondents who attended training before & after ROP

With respect to the training topics attended by the respondents (n = 58) it was observed that few of them had the opportunity to attend training on nursery production (3% of respondents) and vegetable production techniques (7% of respondents) before the vegetable ROP was started. But after the ROP more than 15% of the respondents got trainings on complete package of vegetable production techniques (Figure 7).

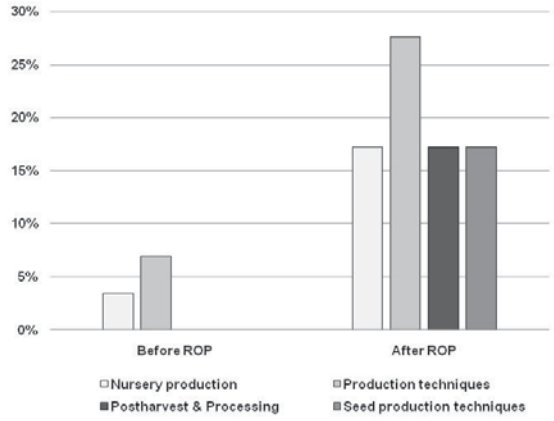

Figure 7. Percent respondents attended training before & after ROP by topics

3.7 Impact on household income

To increase the household income through sell of various vegetable products is one of the major objectives. To measure the impact of the vegetable ROP implemented it is essential to compare the income generated from different means of cash income sources. The study revealed that there was positive impact of the vegetable ROP on the household income generation. In all the villages there was increase in household income after ROP when compared to before ROP by 64%, 92% and 71% increase in annual mean income in Drepong, Laptsa and Zunglen villages respectively through vegetable production (Figure 8).

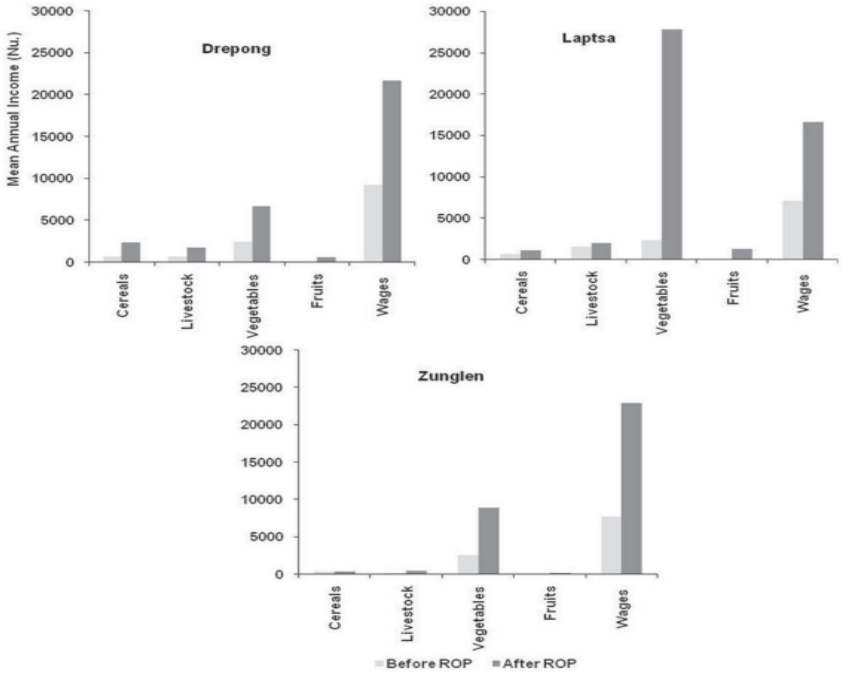

Figure 8. Mean annual income from different sources

3.8 Constraints in vegetable production

As per the responses from the farmers, they perceive unavailability of seeds, problems of diseases, problems of pests, irrigation and lack of technical know-how towards increasing productivity and income from vegetable production. More than 70% (n=58) of the respondents said that these were the major problems before as well as after ROP, however, after

the ROP and currently the problem especially on unavailability of seeds, irrigation and technical know-how got reduced (Figure 9).

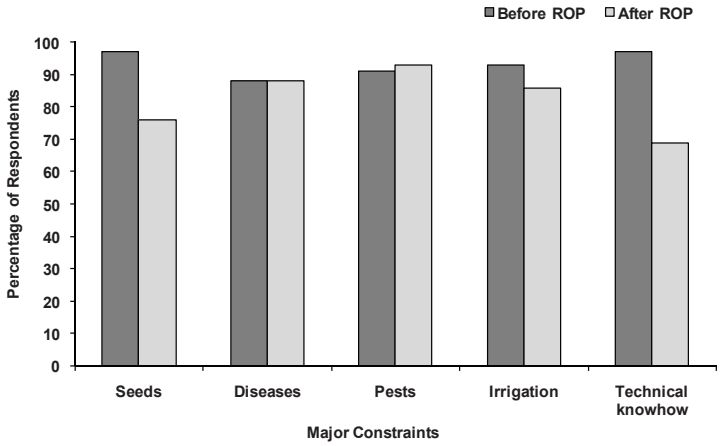

Figure 9. Respondent perception on constraints in vegetable production

The village wise results indicate that the problem of unavailability of seeds and lack of technical know-how on vegetable production have been improved after the vegetable ROP in villages where ROP was implemented and taken up by the groups (Table 2).

Table 1. Perception of respondents on constraints in vegetable production in village

Major constraint	Percentage of respondents					
	Drepong (n=19)		Laptsa (n=22)		Zunglen (n=17)	
	Before ROP	After ROP	Before ROP	After ROP	Before ROP	After ROP
Unavailability of seeds	89	95	100	41	100	100
Problem of diseases	74	68	74	95	100	100
Problem of pests	84	84	91	95	100	100
Problem of irrigation	100	95	81	68	100	100
Lack of technical know-how	89	58	100	54	100	100

4. Conclusion

The results indicate that there was substantial benefit for the farmers through the vegetable ROP. There was positive impact on the vegetable production and livelihood of the people of these three villages after the vegetable ROP was started. It is obvious that vegetable group members of Laptsa and Drepong villages were direct beneficiaries of the program since maximum support was provided to the group members of these two villages, but it was observed that those farmers who are not into the group members also benefited indirectly from this program by means of easy accessibility to improved varieties of vegetables and technical know-how and thereby increase in their vegetable production area, productivity and household cash income when compared to that of before ROP.

The ROP approach considers providing all the technical and material support to the farmers of an area; hence it is an approach that delivers the research technologies directly to the farmers effectively. ROP promotes group farming mainly to encourage working together and initiate co-opertive practices for proper utilization of resources.

Among the two vegetable grower groups formed by RDC Wengkhar with the implementation of the vegetable ROP, the Laptsa group was and is actively involved in vegetable production. Hence, maximum support was provided to this group during the period of vegetable ROP which resulted in maximum increase in all the parameters analyzed when compared to that of group in Drepong. Zunglen village despite having not enjoyed the continuous support from RDC Wengkhar till date had shown reasonably positive impact in vegetable production and household income from vegetables. This indicates that there was positive dissemination of technologies from ROP benefited villages to non-ROP benefited village, which to some extent also indicates the existence of farmer-to-farmer extension system in the geog.

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Efficacy of locally available plant materials in controlling potato tuber moth infestation of potato in stores

Pema Wangchuk[13]

Abstract

Potato tuber moth is a very important pest of potato both in the field and stores. It is more important in the stores as the market value of the infested tubers is completely reduced. Use of insecticides in the stores can cause a grave health risk to consumers and farmers. In order to manage the pest in the stores, IPM options have to be explored. This study was conducted to assess the efficacy of locally available botanicals like Eupatorium adenophorum, Cannabis sativa and Artemisia myriantha in controlling infestation of tubers by potato tuber moth. Results has shown that least number of infested tubers was observed in the tubers covered by Artemisia myriantha (42%) followed by Cannabis sativa and chemical treatment (52%). The infestation intensity was very high for control with 3.4 holes per tuber whereas it was ≤1 when non-chemicals were used. The non-chemicals provide a physical barrier between the tubers and the pest due to its repellant properties. It can be combined with other components to effectively control infestation in stores.

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Keywords: *Phthorimaea operculella*; *Solanum tuberosum*; IPM; botanicals; efficacy; natural repellants

1. Introduction

Potato tuber moth (*Phthorimaea operculella* Zeller) is one of the most damaging insect pests of potato in both the field and storage. It is economically more important in warmer climates. For its rapid growth and multiplication, temperature is most critical. An average daily temperature of 20-25^{o}C is optimum for its development (Raman, 1988). The larvae of the pest affect both the aerial parts and tubers in the field. However, tuber infestation is more important as it lowers or completely removes its market value. Moreover, potato tubers kept in farm stores are also infested by the

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larvae. The potato tuber moth is a very important pest in many countries (Hanafi, 1999). Records from studies showed storage losses of up to 100% in India (Rahman, 1944) and the Phillipines (Das, 1995), 90% in Kenya (Ojero, 1980; cited by Das, 1995), 86% in Tunisia, Algeria and Turkey (Anon,1980; cited by Das, 1995). This pest has become so important in most of the countries in the tropics and sub-tropics that in some, governments had to formulate legislation for its control (Das, 1995). It is also emerging as a serious problem in some potato growing regions of Bhutan. In Bhutan the problem of potato tuber moth infestation in stores is mostly found across regions that are in the elevation range of 1700-2400 m (BPDP, 2006) where the temperatures are optimum for its activity. In the BPDP survey (2006), 29% of respondents mentioned it to be the most important storage problem. The survey also found 95-100% damage of tubers in some farm stores due to tuber moth infestation. In another survey carried out in 2009, an average of 35% tuber damage in stores was observed (Wangchuk, unpublished) with 100% tuber damage recorded in some stores.

Since it is difficult for farmers to identify symptoms of infestation in the field, control of the pest is more important in storage than in field (Kroschel and Koch, 1996). Many studies have been conducted to manage potato tuber moth both in field and storage especially to substitute use of insecticides for potatoes in stores as it is not safe for consumers. Moreover, there are chances of pest developing resistance to chemicals if used frequently (Das et al., 1992; Das, 1995). Because of these reasons, many workers have reported that Integrated Pest Management (IPM) approach is apparently the only way to manage PTM in stores (Das et al., 1992).

Use of plants, called as botanicals, which are natural repellants, is one component of IPM approach. Many plants have been used as natural repellants in management of potato tuber moth in potato stores. Infestation was reduced when potato tubers were covered with chopped and dried leaves of *Ambrosia artemissifolia* L and *Eupatorium odoratum* L (Lal, 1987), *Cannabis sativa* (Kashyap et al, 1992) and also when tubers were stored with garlic bits (Sen, 1954). In our study, we looked into the efficacy

of locally available plant materials in Bhutan, used to provide physical barriers, in managing potato tuber moth infestation and damage of tubers in stores.

2. Materials and Method

In order to provide relatively higher temperatures for our storage trial in the months of October to December, the trial was set up at Renewable Natural Resources Research and Development Sub-Center, Lingmithang, Mongar. The altitude of this location is 638 m above sea level so the temperatures are higher even during those three months, which is optimum for the pest activity and subsequently, infestation. To assess the level of tuber infestation by potato tuber moth, clean, un-infested seed tubers were used. In order to ensure high pest pressure, infected tubers, collected from farm stores, were placed alongside the clean tubers in the store, as a source of the pest.

Both the clean and infected tubers were put in crates and kept in the store. The clean potato tubers used for the trial were subjected to the treatments as follows: 1) untreated control; 2) Chemical (0.1% Fenvalerate); 3) *Eupatorium adenophorum* ; 4) *Cannabis sativa*; 5) *Artemisia myriantha*. Dried and chopped form of the plants (treatments 3, 4 and 5) was used to cover tubers to 2-3 cm layer thickness. For the chemical treatment, tubers were soaked in 0.1% fenvalerate for ten minutes at the beginning of the trial. For control, the tubers were subjected to none of the treatments and left as it is.

A randomized complete block design was used. Each treatment contained 50 tubers in a crate of dimensions 36cm x 28cm x 18cm and was replicated four times. All tubers in different treatments were exposed to potato tuber moth infestation during storage. After 100 days, before the planting time, tubers were observed for frequency of infestation (percentage of the number of infested tubers; a tuber with even one infestation point is counted as infested) and intensity of infestation (number of infestation points per tuber) as described by Kroschel et al (1996). ANOVA for treatments was tested for significance using treatment as the fixed factor

and replication as the random factor. Tukey's HSD test was used when applicable to test the difference between treatments.

3. Results

3.1 Frequency of infestation

The values in Figure 1 are expressed as percentage of infested tubers to the total number of tubers used for each treatment. The difference between the treatments was highly significant (P= 0.009**; Figure1 and Figure 2). 100% infestation was observed in the control. Potato tuber moth infestations on tubers were significantly lower in the treatments with chemical and plant materials than in the control.

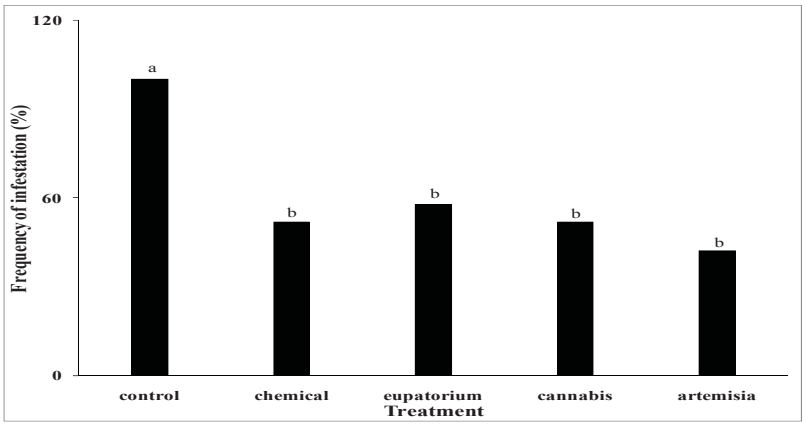

Figure 1. Frequency of infestation. Columns with same letters are not significantly different based on Tukey's HSD test at 5% levels of probability.

However, the infestation levels between treatments with chemical and the three plant materials did not differ significantly although the least number of infested tubers was recorded in the *Artemisia* treatment (42%) followed by *Cannabis* and chemical treatment (52%). These plants are natural repellants and acted as a physical barrier between the tubers and the pest thereby reducing infestation and damage of tubers.

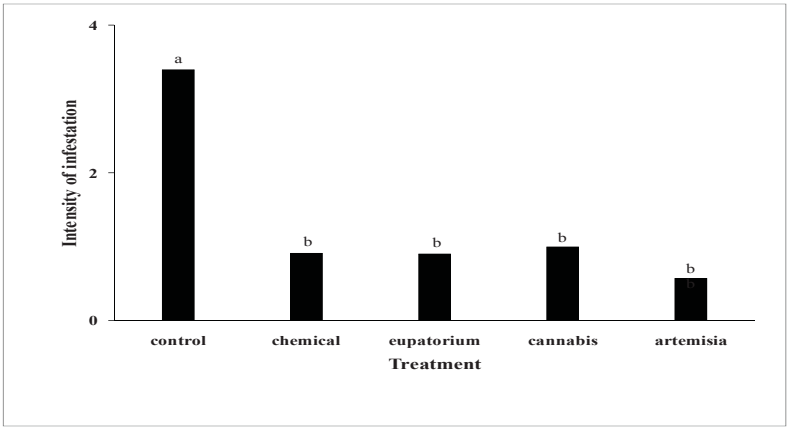

Figure 2. Intensity of infestation. Columns with same letters are not significantly different based on Tukey's HSD tests are 5% levels of probability

Although, it was expected that the chemical treatment would be relatively more efficient in controlling infestation, the plant materials used were also equally efficient as the chemical treatment. This could be attributed to the fact that the tubers were treated with the chemical only once when the trial was set up because of which the chemical treatment must have become ineffective to protect tubers from the pest after a certain period of time during storage.

3.2 Intensity of infestation

The difference in the intensity of infestation between the treatments was highly significant (P= 0.001**; Figure 2 and 3). The intensity was very high for control with 3.4 holes per tuber whereas, number of holes of ≤1 was recorded when tubers were treated with the chemical or covered with the plant materials. Least number of infestation points or holes was observed in the *Artemisia* treatment (0.6). On the other hand, similar values (0.9-1.0) were recorded for the chemical, *Eupatorium* and *Cannabis* treatments. The intensity of infestation was 27%, 27%, 30% and 17% of that of control for chemical, *Eupatorium, Cannabis* and *Artemisia* treatments respectively. Very low level of damage was found on the treated tubers when compared to those of the control which were damaged severely due to the high intensity of infestation.

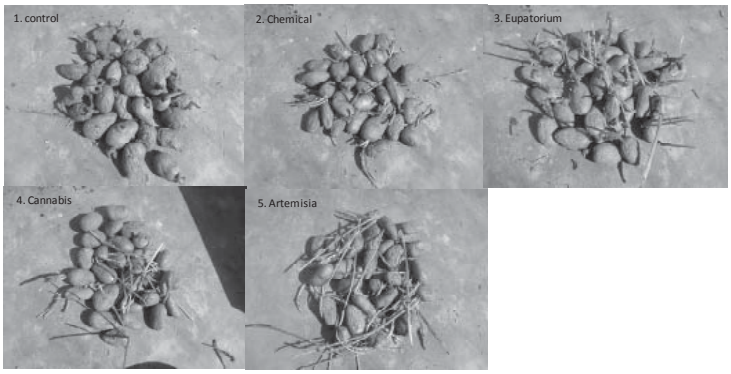

Figure 3. Tubers after 100 days of storage under different treatments

4. Discussion

Covering tubers with dried and chopped plant materials like weeds act as a physical barrier and a repellant against potato tuber moth (Raman et al, 1983). Weed species like *Lantana* in tropical countries and Muna (*Minthostachys* sp) in the Andes when used to cover tubers in a thin layer about 2 cm thick, reduced tuber damage by PTM significantly to <3% (Raman et al, 1983). Weeds like *Artemisia myriantha, Cannabis sativa* and *Eupatorium adenophorum* are available in abundance in Bhutan and are easily accessible to the farmers which can be used in potato stores.

We found that while 100% of the tubers in the control were damaged with an average of 3.4 infestation points per tuber, both the frequency and intensity of infestation was lowest in *Artemisia* treatment (42% and 0.6 respectively) compared to other treatments although not significantly different. This shows that the un-protected tubers in the control were exposed to repeated infestations by the potato tuber moth in the course of the three month storage period. On the other hand, *Artemisia* which has, even by physical assessment, the most pungent odour compared to the other two plants could have been more efficient in repelling the pest and thereby reducing infestation.

Lal (1987) reported only 22% and 21% tuber infestation by potato tuber moth by covering tubers with *Artemisia* and *Eupatorium* respectively as compared to 75% in untreated tubers. However, in the current study, higher infestations of 42%, 58% and 100% were recorded when covered with *Artemisia, Eupatorium* and in untreated tubers respectively. The pest pressure in our study could have been relatively higher than that of Lal

(1987). Moreover, we used fewer tubers and were not heaped because of which every single tuber could have been exposed to infestation especially in the control. Hence, the higher rate of infestation in the current study. *Cannabis* also reduced the infestation to around 50% of that of the control. The efficacy of *Cannabis* leaves was tested by Kashyap et al (1992) and reported that it protected tubers from potato tuber moth up to 120 days.

Our result showed significant difference in infestation between the untreated control and the treated tubers using chemical and plant materials. Moreover, the plant materials used were also as/more effective than the chemical treatment. However, it should be noted that covering the tubers with the plant materials will be effective only for un-infested tubers and does not protect tubers that already have larvae/egg in it. This is because the dried chopped leaves of the plants only acts as repellants and do not possess any insecticidal properties. Hence, a separate study is necessary to assess the insecticidal properties of the plant extracts. Although, effective in controlling potato tuber moth infestation of tubers in storage, use of chemicals should not be taken as a long term solution because of the possibility of potato developing resistance to it if used frequently and the health risks it poses to consumers and producers. However, we should identify various other options, including local knowledge, along with using locally available resources in developing an integrated approach to controlling this pest.

5. Conclusion

From the results that we obtained, it is clear that plant materials which have repellant properties can effectively protect potato tubers from PTM infestations in stores. *Artemisia myriantha* proved to be more efficient that the other weeds and the chemical though the difference was not statistically significant. This is probably the most abundant of the weeds available which can be used by farmers. However, the control is only effective when used on clean tubers and would not be effective if the tuber is already infested or if the moth has already laid the eggs in the tuber. Therefore, the importance of controlling potato tuber moth both at the field and storage level should be understood. Moreover, it also requires the

application of various control components at different stages of the crop growth to keep population and infestation below the threshold level. So, when advocating this knowledge to farmers, it has to be made clear that the leaves of trees and shrubs used to cover potato heaps only protects the tubers from PTM infestation by providing a physical barrier whereas, it may not provide any protection against larvae hatched from eggs that were already laid in the tubers while in the field. Thus, it has to be combined with various other management practices in order to be effective.

Acknowledgement

This study was supported by the Austrian Development Agency through the project entitiled "Development and application of ecological approached to pest management to enhance sustainable potato production of resource poor farmers in the Hindu Kush Himalaya region". We would like to thank Professor Jurgen Kroschel and Dr. Marc Sporelder of the International Potato Center for the valued inputs for this study and on pest management issues of potato in Bhutan. We are also grateful to Mr. Sonam Tashi, Mr. Karma Tenzin, Mr. Pema Gyeltshen of RNR-RDC, Wengkhar and Mr. Sangay, Potato Field Coordinator, Khangma for monitoring the trial as per the protocols provided. Finally, we would like to thank the RNR-RDC, Wengkhar for providing both its staff and place t o carry out this trial.

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LIVESTOCK

Prevalence of Endoparasitic Infection in Stray Dog Population of Bhutan

Nirmal Kumar Thapa[14], Phuntsho Wangdi, Sangay Lham

Abstract

In Bhutan, the stray dog population is very high and they are seldom or never dewormed and hence harbour many endoparasites including of zoonotic in nature. The survey was conducted to study the prevalence of different endoparasites. Coprological survey was carried out in stray dogs from Thimphu municipality and other areas where the stray dogs were impounded to assess the prevalence of these endoparasites. 470 numbers of fresh fecal samples were collected from dog pounds from Thimphu, Zhemgang, Chukha, Gelegphu and Paro. Laboratory findings revealed highest overall prevalence rate of Ancylostomum (hook worm) infection (19%), followed by Toxocara (9%), Troglotrema (5%), Isospora (4%), Trichuris (2%) and Diphylobothrium (< 1%). Ancylostoma was common in all the areas with highest in Zhemgang (41%). Next common helminth was Toxocara present in all areas except Ngalephu with its highest prevalence in impounded dogs from Chhuka (24%). Another 18 number of coprological samples collected from stray dogs from Thimphu city were tested at Institute of Parasitology, University of Zurich, Switzerland with Coproantgen ELISA detecting 6 samples positive for coproantigen against Echinococcus granulosus and two samples for Taenia hydatigenia. Through floatation in sieving technique, Taenia eggs were isolated and identified from 4 samples. Polymerase chain reaction (PCR) analysis from these isolated eggs also detected Echinococcus granulosus.

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Keywords: Endoparasites; Ancylostoma; Toxocara; Echinococcus; Coprology; Stray dogs

1. Introduction

Endoparasites play an important role in health of the animal especially dogs. Among endoparasite, protozoan and the helminthes are

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considered as one of the most important enteropathogens especially in new born puppies (Blagburn et al., 1996). It causes malnourishment including anemia especially in pups due to hook worm infestations. Heavy infection with endoparasites also causes deaths especially in young pups. Dogs also play an important role in transmitting the zoonotic diseases due to parasites such as Toxocara, Ancylostoma and Echinococcus because of its close association with human beings commonly in children. Therefore, human becomes more vulnerable to zoonotic parasitic infections since the stray dogs are seldom dewormed and are often used as companion animals and always remain in close proximity of humans. The main risk of getting infection in human is through environmental contamination like soil and gardens and public places contaminated with dog feces containing parasitic eggs (Halbluetzel et al., 2003, Martinez et al., 2007). In Bhutan, stray dogs also live in a very close proximity with humans due to compassion thereby elevating the risks of parasitic zoonotic infection particularly through contamination of environment with the helminthes eggs through feces. Very high prevalence rate of hook worm infection which is of zoonotic importance has been detected in other developed countries like Australia. In Bhutan, no study has been conducted particularly covering the stray dogs in different regions. The findings would help in formulating the control program thereby reducing the public risk.

Hence, the survey was aimed to identify the different types of endoparasites in stray dogs prevalent in different parts of the country especially in the impounded dog population. The study was also aimed for baseline study for other important zoonotic parasites like Echinococcus for further collaborative study with Institute of Parasitology, Zurich, Switzerland.

2. Materials and Method

2.1 Sample collection

The dogs included in this study were stray dogs from dog pounds and those captured for sterilization by Humane Society International (HSI) during 2009 for Catch, Neuter, Vaccinate and release program (CNVR). The coprological samples were collected from the impounded stray dogs in few of the districts (Thimphu, Paro, Chukkha, Sarpang and, Zhemgang) where the dogs were impounded. At Thimphu, samples were collected from the dogs caught and brought for sterilization. Few districts submitted the

samples by themselves through District Veterinary Laboratories. In total 470 numbers of fecal samples were collected from seven dog pounds from different parts of the country. Ngalephu, Gelegphu, Chhukha, Zhemgang, Memlakha, Thimphu, Tshento Paro and Thimphu municipality.

2.2 Coprology

The samples were examined using standard protocol viz; flotation, sedimentation and stroll's dilution techniques at National Centre for Animal Health (NCAH) Serbithang for helminths. It is very difficult to isolate and identify Taenid eggs in feces by routine procedures; they require special technique. During 2011, 18 number of coprological samples from stray dogs from Thimphu city were hand carried and tested at Institute of Parasitology, University of Zurich, Switzerland . The Taenid eggs were isolated and examined with the help of floatation and sieving technique alternately as described by Mathis et al (1996). About 2 gm of faecal samples (n=18) was taken in a 15ml tube and PBS-Tween buffer was added up to 8 ml and after vigorously shaking it was kept in the fridge for overnight (24 hrs in 4^{o}C). Next day the mixture was centrifuged at 1600g for 10 minutes and about 1.5ml of supernatant was taken and stored in fridge -20^{o}C for coproantigen test and the rest supernatant was discarded. The sediment was mixed with about 8 ml of zinc chloride solution of density of 1.45g/ml. After proper mixing, it was centrifuged at 400g for 30 minutes. The supernatant was passed through the sieve with mesh size 41 um where the Taeniid eggs passes through and was retained at sieve of 20 um . The sieve was put up side down in a funnel standing in a collecting tube with flattened side. Taenids eggs were collected by washing the sieve thoroughly with water. The collected material was examined for taenid eggs.

3. Result and Discussion

Laboratory findings revealed highest overall prevalance rate of Ancylostomum (hook worm) infection (19.97±4.68%), followed by Toxocara (9.32±3.03%), Troglotrema (5.3±4.29%), Isospora (3.87±1.91%), Trichuris (2.41±1.15%) and Diphylobothrium (<1%) (Figure 1). The highest prevalence of helminthes identified was Ancylostoma similar to the findings of Dada et al., (1979) in Nigeria; 87% in stray dogs and 51% in pet dogs in Australia (Boreham and Capon, 2006) and as high as 53.8% in South Africa (Mukaratirwa and Singh, 2010). Even by identification of

worm from the necropsies of stray dogs, Ancylostoma was detected highest (Sadighian, 1969 and Eguía-Aguilar et al., 2004). On the contrary, the prevalence of Ancylostomum was only about 3% and 5% respectively in stray and abandoned dogs in Switzerland (Deplezes et al., 1995). However, no Ancylostomum was detected in the dogs housed in the animal control centre in Spain (Martinez et al., 2007). Next common helminthes identified were Toxocara unlike in other countries where it was found to be highest about 17.4% (Vanparijs et al., 1991) in Belgium;17.7% in Spain (Martínez-Carrasco et al; 2007).

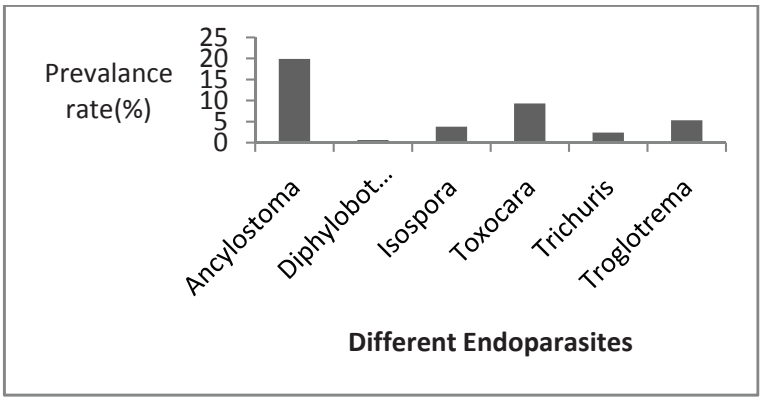

Figure 1. Prevalence rates of different endoparasites in stray dogs

Table1. Prevalence of endoparasites in different parts of Bhutan

Different endoparasite	Troglotrema	Ancylostoma	Trichuris	Toxocara	Isospora	Diphylobo-thrium
Ngaliphu (n=46)	30.4	10.9	6.5	-	2.2	-
Gelegphu (n=60)	6.7	5	5	1.7	10	3.3
Chukkha (n=33)	-	9.1	-	24.2	12.1	-
Zhemgang (n=32)	-	40.6	-	6.3	-	-
Memlakha (n=50)	-	24	-	10	-	-
Paro (n=37)	-	24.3	5.4	10.8	-	-
Thimphu (n=80)	-	25.9	-	12.3	2.8	0.9
Mean $\pm$ SE	5.3 $\pm$ 4.2	19.9 $\pm$ 4	2.4 $\pm$ 1	9 $\pm$ 3	4 $\pm$ 1	0.6 $\pm$ 0.4

Ancylostoma and Toxocara were found common to all the places of survey (Table 1). Since these are important zoonotic Helminths, the dogs should be dewormed whenever possible. Fecal samples of Dungbe,

Zhemgang revealed very high worm load of *Ancylostomum* with 500-2000 eggs per gram (EPG), which is also detected in most parts of Bhutan. Samples from Memelakha, Thimphu revealed worm load of Toxicara sp. with 200-800 EPG and hook worm of 200-900 EPG. However, from the second lot of 18 numbers of coprological samples from stray dogs in Thimphu city hand carried and tested at Institute of Parasitology, University of Zurich, Switzerland with Coproantgen ELISA revealed 6 samples detected positive for copro antigen against *Echinococcus granulosus* and 2 samples for *Taenia hydatigenia*. Through floatation in sieving technique, Taenia eggs were isolated and identified from 4 samples. Polymerase chain reaction (PCR) analysis from these isolated eggs also detected *Echinococcus granulosus* cattle strain.

4. Conclusion

This study revealed that the stray dogs are found to be infected with Ancylostoma and Toxocara both of which are of zoonotic importance. The second lot of samples tested at Switzerland revealed positive to Echinococcus which is also of zoonotic importance. Hence, stray dogs needs to be dewormed whenever possible or feasible. Usually CNVR for stray dog population control, it is mandatory to deworm these dogs. Since these dogs are hardly dewormed once a year the deworming is not enough and these dogs carry the worms which continue to contaminate the environment posing risk to human population.

Acknowledgement

I would like to thank, Professor, Dr. Peter Deplezes and Dr. Zaidov Iskender, Institute of Parasite, University of Zurich, Switzerland for training in the techniques of isolation and identification of Taenid eggs and also PCR analysis of the parasite eggs. Their financial support and also using of chemicals and reagents free of cost is highly indebted. I also would like to thank, International Foundation for Science, Stockholm, Sweden for supporting my travel to Zurich, Switzerland for acquiring hands on training on the diagnostic techniques.

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Status of Himalayan Cliff Bee in Bhutan

Gyem Tshering[15]

Abstract

Bhutan is considered as the home tract of Apis laboriosa. A study was initiated to record and document its population status, habitats, floras, migration patterns and predators in the east central region of Bhutan. The required information was collected using semi-structured questionnaires and informal discussion. Twenty eight sites with 290 colonies of A. laboriosa in five districts were recorded at an altitude of 800-3400m asl. The hiving sites were found mostly on the cliff faces with abundant floras. The floral diversity ranges from sub-tropical to alpine forests providing year round forages to the bees.All hiving sites were closer to water bodies. The nesting heights were between 3-150m from the ground. Bees migrated to warmer places in winter and to cooler places in summer. The main predators reported were pine martin, drongo, hornet and bear. The study revealed increasing population of A. laboriosa due to non-existence of honey hunting, religious sentiments and restriction imposed by the government. Wax collected in small quantities was used mostly for domestic purposes. Presence of these bees nearby community is considered a good omen of bountiful harvest and good health and well being.

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Keywords: Apis laboriosa; population status

1. Introduction

Rock bee (*Apis laboriosa)*, a native to Asia (Winston, 1987) is also known as Himalayan Cliff Bee owing to its nesting habits on cliff faces unlike other species of honeybees namely *Apis cerana (*Indian honeybee*), Apis florea (*Dwarf honeybee*), Apis mellipona (*Stingless honeybee*), Apis mellifera (*European honeybee*) and Apis dorsata (*Giant honeybee*)*. This group of honeybees is all found in Bhutan. Bhutan therefore is considered one of the richest in the world as far as bee resources is concerned. *A. laboriosa* is found abundantly throughout the country from 800-3400masl. Its presence is attributed mainly due to the availability of vast floral diversity and rich vegetation cover. The other reason could also be due to

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lesser disturbances (religious sentiments) in its habitats from human populace. Bhutan could be one of the home tracts of *Apis laboriosa,* which is endemic to Himalayas (Ahmad & Roy, 2000).

Apis laboriosa is not domesticated so their honey is collected from the wild. These bees are known to produce 50-80kg of honey per colony (Mishra, 1995). It is found hiving mostly on cliff faces. They migrate to higher places in the summer and return to warmer places in winter. Attempts had been made to domesticate these bees elsewhere but were not successful (Verma, undated). These bees are efficient pollinators of plants and agricultural crops and also an important indicator of ecology to monitor the health of ecosystem (Ahmad & Roy, 2000). Though Bhutan was reported to be the home tract of *A.laboriosa*, yet hardly any studies and documentation was done. Therefore, this study was initiated to collect information on population status, bee habitats, floras, migration patterns and predators of *A. laboriosa* in east crntral region of Bhutan (If you mention just region it appears like we are referring to south asia or something. The objectives are: to study the population status of *Apis laboriosa* and, understand and document bee habitats, floras, migration patterns and predators of these bees.

2. Material and Method

2.1 Study locations

A population trend of *A.laboriosa* was monitored in Bumthang valley for five years (1999-2008) on annual basis in the selected locations. The present study covered Zhemgang, Trongsa, Sarpang and Wangdue districts.

3.2 Data collection

The designated sites were visited and data on number of colonies found in each location, aspect, altitude and coordinates of the nesting sites using geographical positioning system (GPS) collected. Team also met about 30 elderly people to explore more relevant information related to hiving sites, populations, honey hunting, migratory places and bee flora using semi-structured questionnaires. Efforts were also made to actually investigate floral diversity around the nesting locations.

3. Results and Discussion

3.1. Population status and trend

Study conducted in five districts found 28 locations with 290 colonies of rock bees (Table 1). Maximum colonies were recorded in Sarpang and minimum in Zhemgang with average of 10 colonies per location.

Table 1. Number of nesting sites and colonies

District	No. of locations	No. of colonies	Av. colonies /location
Bumthang	18	68	4
Trongsa	3	65	22
Zhemgang	1	3	3
Sarpang	1	120	120
Wangdue	5	34	7
Total	28	290	10

Rinzin and Tenzin (2000) also reported of sighting 55 colonies of *Apis laboriosa* in Bumthang valley. Similarly, 38 colonies were reported in 12 locations in western Bhutan. Population trend of *A. laboriosa* monitored over a period of five years in Bumthang district showed increase of 13 colonies (24 %) (Table 2). Local informants (100%) in the survey areas also reported increased trend of *A. laboriosa* population in their area. The increase was attributed to non-existence of hunting practices due to religious sentiments, difficulty in hunting and restriction by the government. However, Ahmad et al (2003) reported decline in population from a study conducted in Kaski, Nepal. The reasons cited for decline were due to change in land use (deforestation, settlements) system resulting to loss of bee floras, unethical hunting practice and economic opportunity from sale of honey outside Nepal.

Table 2. Number of cliff bee colonies in Bumthang

Geog	No. of locations	1999	2001	2002	2003	2006
Tang	6	22	19	20	22	25
Ura	1	1	0	0	0	0
Chumey	4	7	5	5	6	6
Chokor	9	25	27	32	33	36
Total		55	51	57	61	68

3.2 Habitat

The nesting sites in Bhutan were found between 800-3400masl. Similar observation were made by Pratap (1999) who reported that the nesting sites of *Apis laboriosa* in Nepal, Bhutan, China and India were found at an altitude range of 1200-3500m asl. *Apis laboriosa* combs are commonly found hanging from the cliff faces and in safer places (under the bridges) where there are abundant pollen/nectar and water sources. Example nesting height in was as low as few mentres at Mauri vhir in gelephu. In earlier studies, Ahmad & Roy (2000) reported nesting height above ground of as low as 3m to a high of 150m In winter, some colonies were found hiving in cracks and crevices to a height less than a meter from the ground. This was to keep the bees warm and protected in the winter. Ahmad et al (2003) also reported similar findings in Kaski, Nepal. Water is an important factor for selecting hiving sites as most sites were located nearby water bodies. The distance from the water sources was found not more than 150m from the nesting sites. Ahmad et al (2003) also reported similar hiving pattern in Bhutan and Nepal.

About 60 percent of the cliffs faced south or southwest which indicates needs for good sunshine for the bees for their daily activities. The above finding also is agreement to Ahmad (2003) who reported that prolonged photoperiod enabled the bees for a longer day length for foraging.

3.3 Vegetation and floras

Bhutan has rich floral diversity. The floral diversity ranges from sub-tropical to alpine forests providing year round forages to the honeybee species. The sub-tropical forests provide rich floral sources ranging from shrubs, trees and variety of agricultural and horticultural crops.

Temperate zone has equally rich and diverse mixed vegetation and flowering plants. Besides, clover, buckwheat, potato and other vegetable cultivation provides good source of nectars to the bees.

3.4. Seasonal migration

Apis laboriosa are migratory bees. These bees migrate to warmer areas from October in winter and to cooler places in summer from April. They migrate to places as low as 800m to a high of 3400m asl. It was

observed that the bees nesting above 2000m totally migrates to warmer areas in winter. Some of the bees nesting in comfort zones between 1200-2000m remained on a cliff throughout the year. In such cases, bees moved to more protected areas at the base of the cliff, cracks and crevices. Ahmad et al (2003) also reported similar findings in Nepal.

3.5 Predation

The main predators according to the informants were hornet, drongo (*Dicrurus* sp), bears, eagle, pine martin and man. Drongo predates on bees on flight and while foraging. Ants also create nuisance to the bees and feed on combs. Hornets pose serious threat to the bees in their nesting places. Bears also attack the colonies which are located in the accessible places nested only few metres above ground.

3.6 Honey hunting

The past study revealed the existence hunting of *Apis laboriosa* of honey in Bhutan. Breadbear (1986) cited by Verma (1990) reported Sarpang, Gelephu, Trongsa, Paro and Phuntsholing as major places of honey hunting operations in Bhutan. Ghallay (2003) also reported some cases of hunting by herders and road workers. However, present study in the five districts revealed that the hunting was not continued due to religious sentiments, difficulty and risk involved for the hunters and restriction by the government as it is considered part of forest resources.

3.7 Socio-economic importance

Bees play vital role in the pollination of large numbers of agricultural crops. However, their importance is underestimated by many. Besides pollination, the presence of bees in the locality was considered good omen by the community of bountiful harvest and sound health (ward away evil spirits). Although honey hunting was not common; honey from *A. laboriosa* was considered for its medicinal value. Ahmad et al (2003) also reported that *A. laboriosa* spring honey from Rhododendron was considered a premium priced honey for medicinal qualities with relaxing properties used as sedatives. It is exported in large amount to Japan, Korea, and Hongkong. Wax collected in small quantities by farmers was used for domestic purposes and sometimes sold. In the past, people use to market it to India. Roder (1998) reported that bees wax was once the major export items of Bhutan during 19th century. Now it is increasingly sold within the

country especially to Beekeeping Association of Bhutan in Bumthang. It is used mostly for making foundation sheets in *A. mellifera* honey production. Wax collected for domestic purpose is used for sealing cracks of wooden containers; insulate threads and metal casting. Krell (1996) also reported wide range of uses like candle making, metal castings, cosmetics, varnishes and polishes, food processing, textiles and medicines. A kilogram of unprocessed wax fetched up to Nu. 200. With the expansion of the beekeeping enterprises, the demand for wax would increase in future. Therefore, illegal and unsystematic wax extraction might threaten these bees' survival.

3.8 Constraints

Some of the problems that hindered proper monitoring and closer studies were:

- Lack of expertise and equipments
- Inaccessibility of most hiving sites for closer observation

4. Conclusion

Population trend of *A. laboriosa* in Bumthang over the period of five years showed an increase of 24% indicating that environment is still pristine and forests is providing adequate forages for these bees. Further, predators though are found to destroy few of the bee colonies, absence of honey hunting due to religious sentiments and restriction by the government has contributed to increased population status of the bees. The nesting sites were found between 800-3400masl. Nesting height above ground was found between 3m to 150m. All south facing hiving sites and its nearness to indicates that water sources and sunshine is the most important criteria for the nesting sites by these bees. To avoid extreme weather conditions and its adverse affect, these bees migrate to warmer areas in winter and to cooler places in summer. However, bees nesting between 1200-2000m where weather is quite favourable for survival remained on a cliff throughout the year.

Acknowledgement

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Computer Simulation- A Useful Tool for Decision Making in Village Poultry Rearing Options

Tshering Gyeltshen[16], Henk M.J. Udo, Fokje Steenstra, T.C. Viets

Abstract

The aim of this study was to model improvement options for village poultry production in different systems. Data from 38 households in Denchhukha and 39 households in Yoeseltse under Samtse district were collected through household survey using a semi-structured questionnaire on poultry rearing and production. Flock data and production data for the period September 2009 to September 2010 were collected through the interview. The VIPOSIM® simulation model was used to test different intervention options for improvement in flock size and production as compared to base situation. Daytime housing of chickens, chick housing and crossbreeding were used as improvement options for simulation. Poultry rearing was for dual purpose of meat and egg production in Denchhukha while in Yoeseltse, it was mainly for eggs in Buddhist communities and for dual purpose in Hindu communities. Predation is the most important constraint in both the blocks. Simulations with different interventions showed that daytime housing had the maximum positive effect on the flock size but resulted in net loss to the farmers. Chick housing seemed to be economically the most effective intervention in Denchhukha and Yoeseltse dual purpose production. Field experiments to test improvement options can be costly and time consuming. Computer simulation can be a very useful tool and cost-effective method to test improvement options and thus aid in decision making.

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Keywords: Village poultry; simulation; modelling; improvement options; decision making

1. Introduction

Many rural households in Bhutan are known to rear a few number of chickens for household egg consumption. About 66% of rural households are known to rear poultry (NBC, 2011). Because chickens in villages are

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reared under scavenging system, the birds are highly vulnerable to predation by various kinds of prey. Predation is the most important cause for mortality in village chickens in different parts of the country (Dorji and Gyeltshen, 2012; Gyeltshen et al., 2012). Therefore, appropriate and economical interventions are necessary to minimize losses and improve productivity. However, it is often time consuming and costly for experimentations to determine the most suitable and economical intervention options (Udo et al., 2006). Computer simulations have often been used to determine alternative options for improvement (McAinsh and Kristensen, 2004; Rola-Rubzen and Pym, 2004; Udo et al., 2006). Using computer simulations to estimate the production and economic values of alternative intervention options may be a useful tool in Bhutanese context as well. Therefore, the objective of this research was to explore improvement options in village chicken production using computer model VIPOSIM®.

2. Materials and Method

2.1 Data collection

Thirty eight households in Denchhukha and 39 households in Yoeseltse under Samtse Dzongkhag were randomly visited and interviewed using a questionnaire. The questions pertained to poultry management, constraints of poultry rearing, flock dynamics, production and economic values of poultry products. Flock dynamics and production data for the period September 2009 to September 2010 were obtained. The survey interviews were carried out during the months of September and October in 2010.

2.2 Modeling

Village Poultry Simulation model (VIPOSIM®) is a dynamic stochastic model used to explore management options for village poultry systems (Asgedom, 2007; Udo et al., 2006). The model takes into account flock size, mortality in the flock, bird off take (bird sales and consumption), egg production, egg losses, egg off take, and hatching of eggs in different seasons in a sequence of events (Figure 1). Calculations are performed in time steps; each time step is equal to three months, which is one

reproduction cycle, i.e., from a hen laying eggs, incubating and hatching, and chick rearing until she starts to lay again (Asgedom, 2007). Flock size changes with each time step depending on the number of birds in different categories in the previous season. The calculation is performed for 12 time steps. Economic data are taken into account to compare economic performance of a management intervention with the base situation.

In the present study, three management options- daytime housing, crossbreeding and chick housing were simulated for different productions systems. Changes in the input values as a result of each of these interventions are given in Table 1 (adopted from review by Udo et al., (2006).

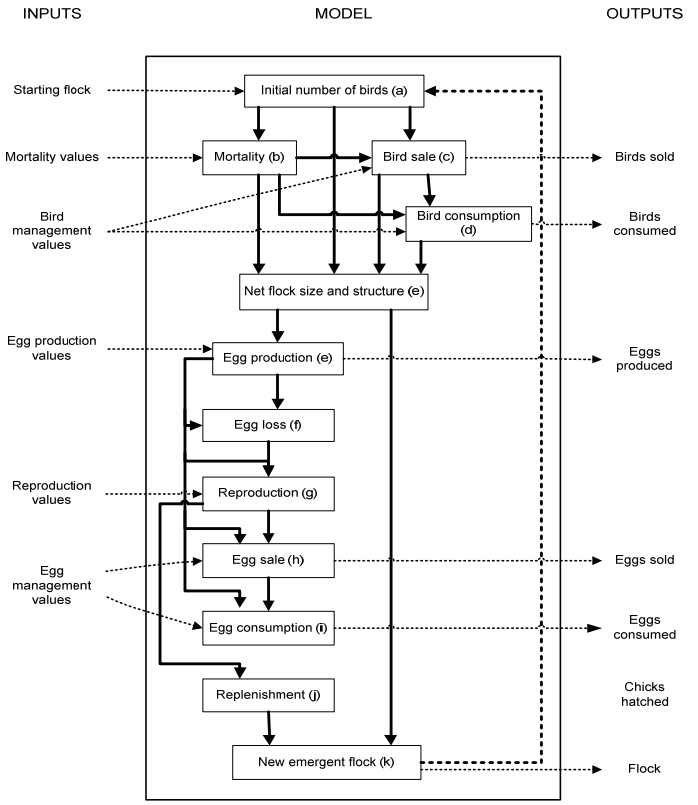


Figure 8. VIPOSIM® model showing the input and output of poultry production systems in time steps (Adopted from Asgedom (2007) and Udo et al (2006).

Table 3. The changes in the input values to the model for different intervention options

Intervention	Change in flock	Feed supplementation required
Daytime housing	Mortality from predation 0% Egg loss 0% Mortality by other reasons 50% lower	80 g, 50 g and 25 g feed for cocks/hens, cockerels/pullets and chicks respectively
Feed supplementation	50% more eggs 15% earlier age at first egg	40 g and 30 g for cocks/hens and cockerel/pullets.
Crossbreeding	15% earlier age at first egg 50% more eggs per hen Mortality from disease 10% higher Mortality from predation 54% higher One season without clutches	40 g and 40 g respectively for adult chickens and cockerels/pullets

Source: Adopted from review by Udo et al (2006)

The economic inputs for the intervention are given in Table 2. The different costs were based on the existing costs in September 2010 and estimations by the extension agents (Rizal, 2010 and Dorji, 2010, *Personal communication*).

Table 4. Prices used for cost -benefit analysis for Denchhukha and Yoeseltse

	Denchhukha	Yoeseltse	Source of data
Cocks	200.00	200.00	Household survey
Hens	150.00	150.00	Household survey
Growers	120.00	120.00	Household survey
Eggs	5.00	7.00	Household survey
Manure (per kg)	2.00	2.00	Assumption
Housing (per year)	700.00	700.00	Extension agents
Chick housing (per year)	250	250	Assumption
Feed (Nu./kg) Layer mesh Grower mesh Chick mesh	 18.40 18.00 19.00	 18.40 18.00 19.00	 Karma Feeds Distributor, P/ling
Feed transportation costs (every two season)	100.00	50.00	Assumption

3. Result and Discussion

3.1 Production Systems and constraints

Poultry rearing in the two blocks are characterized by small flocks of chickens reared under scavenging system. All surveyed households in Denchhukha reared chickens for dual purpose of meat and egg production. In Yoeseltse, Buddhist households (17 households) reared chickens for egg purpose while Hindu households (22 households) reared them for dual purpose.

Figure 2 shows the most important constraints in poultry rearing in Denchhukha and Yoeseltse. Most respondents indicated predation as the most important constraints in both Denchhukha and Yoeseltse. Predation losses from October 2009 to September 2010 were 5.5 birds per household in Denchhukha and 2.3 birds per household in Yoeseltse. A similar study by Conroy et al (2005) in Udaipur district (Rajasthan) and in Trichy district (Tamil Nadu), India, found that predation was the most important constraints in backyard poultry rearing. Improvement in housing for the night shelter may reduce predation losses. Other constraints include diseases, feed and unknown losses of birds.

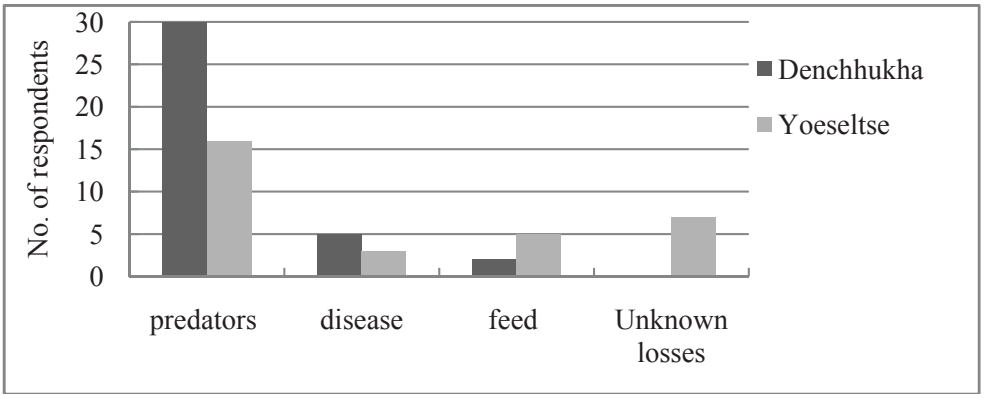


Figure 9. The most important constraints of rearing chickens as perceived by farmers in Denchhukha and Yoeseltse.

3.2 Exploring improvement options

3.2.1 Base situation

Simulations in three production systems- Denchhukha, Yoeseltse dual-purpose production and Yoeseltse egg production systems- were carried out for a period of three years (12 times steps) with the VIPOSIM® model. Farmers considered only two major seasons, winter and summer, based on their cropping pattern. Therefore, season 1 and season 2 refers to winter season and season 3 and season 4 refers to summer. Initial flock size in Denchhukha was 17 birds. The flock size fluctuated over the seasons with a small annual growth in the flock size. In Yoeseltse dual-purpose production, the initial flock size was 19 birds per household. Flock size in Yoeseltse egg production system (8 birds) was smaller than the flock sizes in the two dual production systems.

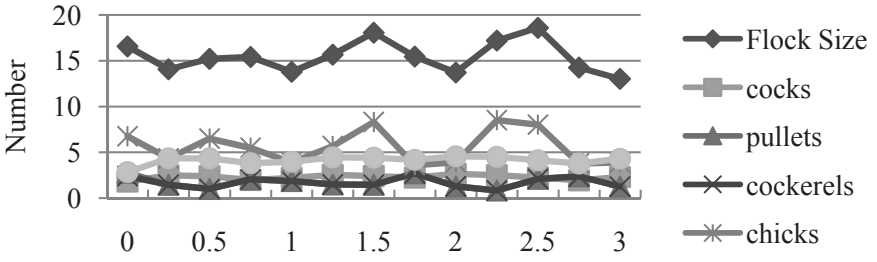
Input values of egg production, rates of egg offtake, incubation and hatching for the base situation in the three production systems- Denchhukha dual purpose production, Yoeseltse dual purpose production and Yoeseltse egg production are given in Table 3.

Table 5. Average egg production, off-take, losses, and reproduction rates in four seasons in Denchhukha, Yoeseltse dual-purpose production and Yoeseltse egg production

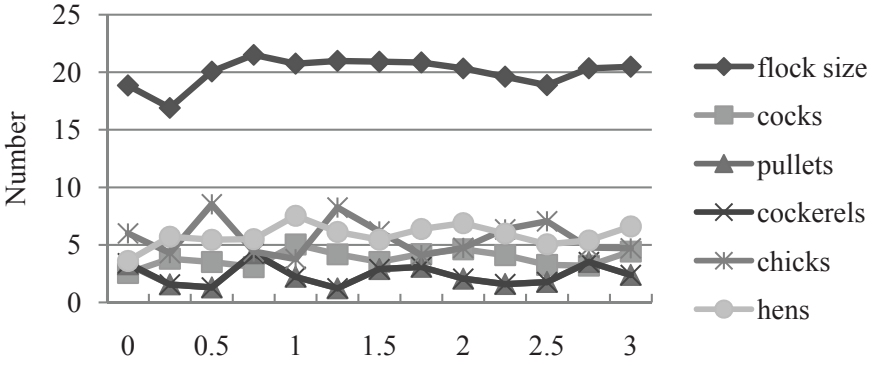
Parameters	Season	Denchhukha	Yoeseltse dual-purpose production	Yoeseltse Egg production
Egg production/hen	1, 2	13.0	8.8	13.8
	3, 4	8.2	10.2	13.4
Eggs consumed (%)	1, 2	69.1	52.9	71.4
	3, 4	64.1	62.5	63.3
Eggs sold (%)	1, 2	12.9	25.4	22.5
	3, 4	17.7	27.5	34.8
Eggs lost/ broken (%)	1, 2	1.3	1.0	1.0
	3, 4	0.9	0.8	0.1
Eggs incubated (%)	1, 2	16.7	20.7	5.2
	3, 4	17.3	9.2	1.8
Eggs hatched (%)	1, 2	84.2	70.7	72.8
	3, 4	79.5	87.4	61.1

Figure 3 shows the number of cocks, pullets, cockerels, chicks and hens for the base situation in three production systems. Data for season 0 were used as input values for season 1 and data for season 2 represents the output from the first time step.

(a). Denchhukha



(b). Yoeseltse dual-purpose production.



(c).Yoeseltse egg-purpose production.

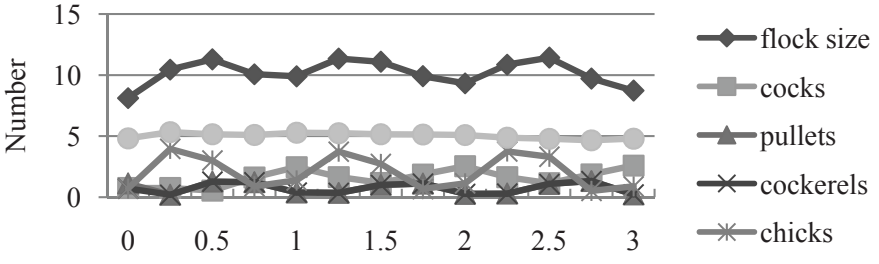


Figure 10. Simulated number of cocks, pullets, cockerels, chicks and hens over a period of 3 years for Denchhukha (a), Yoeseltse dual-purpose production (b), and Yoeseltse egg purpose production (c).

Figure 4 compares the changes in flock size due to different interventions to the base situation over 3 years simulation period. A general trend of increase in flock size with different interventions is seen in all the three production systems.

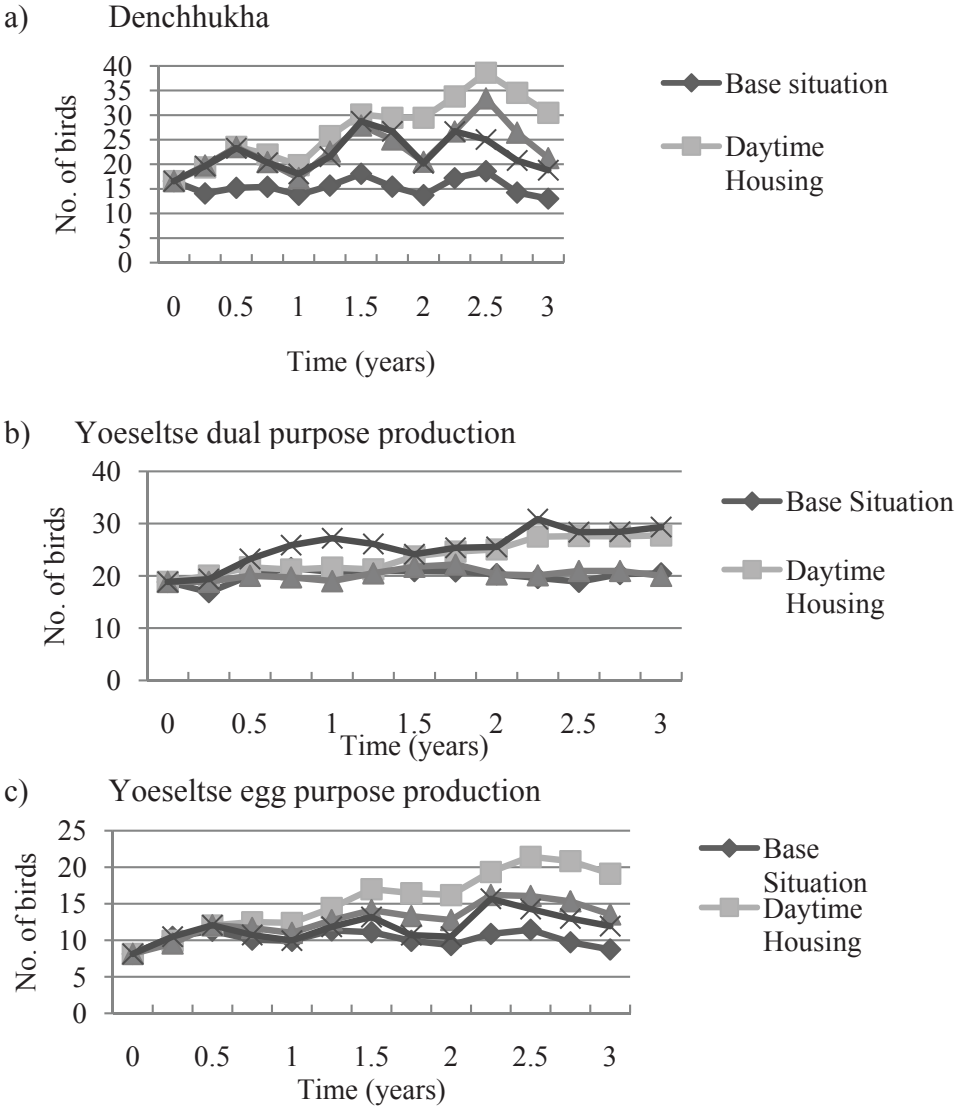
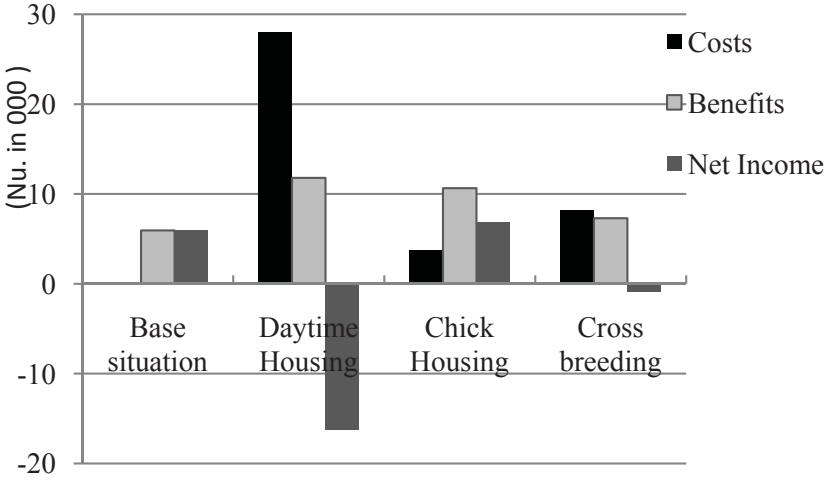


Figure 11. Simulated flock size development for the base situation and different interventions over 3 years for (a) Denchhukha, (b) Yoeseltse dual-purpose production and (c) Yoeseltse egg production systems.

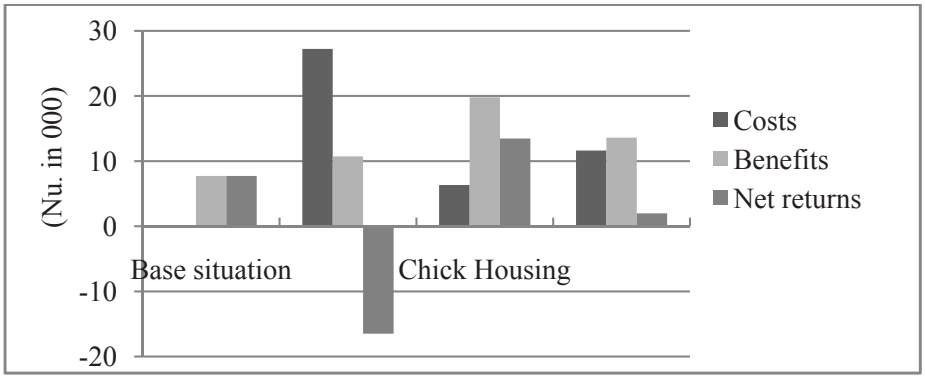
3.3 Cost benefit analysis

Total costs, benefits and net returns from the interventions were calculated for the simulation period of 3 years and compared with the base situation. The net incomes as a result of each intervention in the three production systems are shown in Figure 5. In all three systems, daytime housing of flock incurred losses to the farmers, as housing of birds required feeding of a nutritionally balanced feed to the birds. Therefore, daytime housing of indigenous chickens and feeding them with commercially formulated feed will not be beneficial for the farmers. A similar study in Kenya and Ethiopia by Udo et al. (2006) showed that housing of birds and crossing breeding resulted in net losses to the farmers due to the need to feed the birds with balanced feed. Housing of chicks during the day and thus protecting them from predators had an overall positive effect on net returns in all the three production systems due to increase in flock size and very little additional expenses.

a) Denchhukha



b) Yoeseltse dual purpose production



c) Yoeseltse egg production

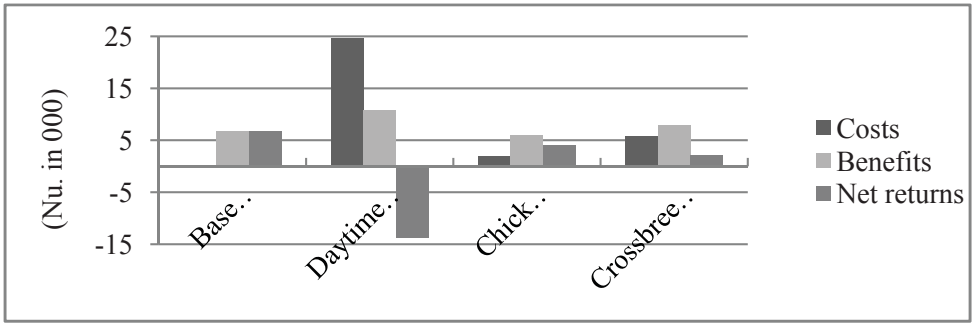


Figure 12. Total costs, benefits and net returns for the base situation, daytime housing, chick housing and feed supplementation for (a) Denchhukha, (b) dual purpose production in Yoeseltse, and (c) egg purpose production in Yoeseltse for a period of 3 simulated.

4. Conclusion

Predation is the most important constraints for the farmers. Although day time housing of the poultry flock has the maximum positive effect on flock size in all three production systems, it is economically not viable due to high expenses incurred to feed them with a commercially formulated feed. Chick housing during the day time seems to be the most beneficial intervention economically in the dual production system. Therefore, housing of chicks could reduce predation losses and bring positive economic returns to the households. Computer model (VIPOSIM®)

is a useful tool for identifying suitable intervention options in short time and with minimal costs that can be used both at individual farm level as well as at village/block level. Hence, it can serve as a useful tool for the farmers and extension agents in decision making with regards to poultry rearing options.

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FORESTRY

Impact assessment on selected socio-economic indicators of farming communities after fencing their agricultural farms using locally fabricated electrical fence in eastern Bhutan

Purna Bahadur Chhetri[17], Tshering Penjor, Choki Nima and Dema Yangzom

Abstract

Human-wildlife conflicts arise due to their co-existence within the same ecological landscape and competition for survival. In Bhutan, the conflicts became widespread in past decades. Many control methods has been experimented by research-extension-farming communities, however, there were no effective method developed so far. Since 2006, research trials had been underway in eastern Bhutan led by the Renewable Natural Resources Research and Development Centre, Wengkhar using locally fabricated electric fence. This study was conducted to understand the before and after impacts of locally fabricated electric fence on key socio-economic parameters of farming communities and its costs. The study was conducted using semi-structured survey questionnaires and focused group interviews of beneficiary households. The results revealed wildlife damaged to crops reduced to less than 10% in the villages. There was significant increase in the improvement of farming livelihood in terms of increase in cultivation area, households' engagement in cultivation, decrease of fallow land, increased time for farming, child care, and no crop depredation by wild animals namely; wild boar, barking deer and free-range domestic animals after the introduction of FEF. It also reduced crop guarding-related disputes and increase food self-sufficiency by 30-40%. The average cost of FEF of Nu.6170/km is significantly lower than the commercial ones. This study concludes FEF brought significant positive changes in socio-economic conditions of farming communities and was cost-effective in reducing crop depredation and human-wildlife conflicts.

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Key words: Locally fabricated electric fence; human-wildlife conflict; socio-economics; food self sufficiency

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1. Introduction

The human-wildlife conflict (HWC) has been way of life ever since human and animals co-exist within the same ecological landscape for their survival (Lamarque et al., 2008). Obviously, the conflict is the result of negative impacts on each other interests on survival. There are many types of HWC such as predation of domesticated animals by wild predators and the loss of livestock to wild predators is livelihood concerns in the trans-himalayan pastoralist societies (Namgail et al., 2007). For mitigating such concerns, Wang et al., (2006) suggests reducing forage competition between wildlife ungulates and domesticated livestock. The success of protection and conservation of any biological resources especially in protected areas depends on the perceptions and attitude of local populations and how plan and programs of protected areas resolved losses of subsistence of local communities (Kharel 1997; Rao et al., 2002). In many cases, the conflict between wildlife and humans especially on livestock and crops seriously set back conservation prospects of mega animals (Madhusudan, 2003). The crop depredation by wild animals is one of the most important human wildlife conflict faced by the Bhutanese farmers. This conflict has direct and indirect consequences in terms of household food security, livelihoods and socio-economic of the rural farmers. Some of the indicators of these problems are increasing rate of abandoning agriculture land and rural-urban migration (Penjor, 2010). There are many stories of HWC in written as well as in oral traditions. Every year there are reports of bear mauling humans and cattle in the country. Lately a man was mauled by bear in Paro (Kuensel, 2011). In fact some of those stories are about killing of precious livestock by mega predators such as wild dogs, tigers and others; and farmers deliberately poisoning carcasses of prey animals to kill the predators. As a result of which many other wild animals in lower strata of food web were said to have been proliferating. The prolific breeders such as wild boars became one of the most damaging that not only destroys the hard toiled crops of the farmers; it slowly changed the demographic patterns in the country, even changed cultural and socio-economic conditions in the rural areas. Likewise other wildlife population was said to be increasing. In absence or presence of very few mega carnivores in the ecosystem, it was said to have contributed towards the increase of wildlife in the country.

For obvious reasons, to counter such situation, the farming communities had opted different methods such as guarding crops. In fact

guarding the crops from the wild animals became a routine farming activity almost for two decades in the country. Apart from guarding crops, farmers had been trying setting up snares, use of scare crows, illegal hunting and many other methods which may not have been recorded so far. One of the methods in use was said to be direct electrical current tapped through naked electrical transmission lines and household outlets. The usage of such methods may have been useful for temporarily keeping the wild animals away. However, it is one of the most lethal methods to both human as well as animals (both wild and domesticated) who are not aware of such practices. Reports in media indicated the illegal use of electric current from homes to fields without connecting to energizers, ended in fatalities; some cases were reported earlier such as 9th October 2009, a report of a farmer electrocuted by improvised electric fence set to exclude crop raiding wildlife. Similar incident was reported on October 23, 2011 in which a man in Yongphu-pam in Trashigang was electrocuted with similar fencing device (Dema, 2009). These are some cases and there could be many unreported.

In some cases, guarding of crops became so burdensome with already farm labor shortage, that farming communities started opting for non-farming livelihood sources for their livelihoods. The crop damaged by wild animals had also contributed to increasing rural-urban migration. Renewable Natural Resources (RNR) statistics showed that field crops losses to wild animals is alarming. More than 55% of the damages of crops were attributed to wild animals (Agriculture statistics, 2010). In its earnest efforts to mitigate the human wildlife conflicts, the Ministry of Agriculture and Forests (MoAF) had developed various strategic measures such as crop compensations, crop insurance, protective fencings such as wire mesh, stone wall and other indigenous measures (Penjor et. al., 2012). Apart from those, MoAF had been developing user-friendly and cost effective devices against the crop predators such as light and sound repellent promoted by the National Post Harvest Centre (NPHC), DoA, sound alarm and solar electric fencing by Wild Life Conservation Division (WCD), DoFPS and use of fabricated energizer by RNR-RDC Wengkhar. Experiences from other countries where wildlife is menace to crop production have reported that electric fencing is one of the most cost-effective and immediate control measures (Kioko et al., 2007; Vidrih and Trdan, 2008; Reddy et al., 2008). The main advantage of using electric fence is that they do not harm the wild animals; hence conflict does not arise from the use of electrical fencing with our conservation efforts. Apart from a temporary electric shock, there is no

known harm done to the animals that come in contact with the electrified wires (Penjor, 2010). The risk of injury to both humans and wild animals are lower than non-electrified fences, especially barbed-wire fences. However, in Bhutan up until now electric fencing has never been evaluated properly except for some trials set up by the Department of Forests against wild elephants in the southern part of the country and those mentioned above.

In RNR-RDC Wengkhar, an electric fence energizer was fabricated by a researcher at the Plant Protection Laboratory and were tested with farmers since 2006 on trial basis. However, its effectiveness, usefulness, safety to human as well as animals had never been verified or studied. The current study was undertaken to assess the impacts of these trials to understand these parameters and lay out the ground work for mass use in farming communities in terms of cost-effectiveness and within the safety standard both for humans and animals.

2. Materials and Method

The data for the study was collected from four locations in eastern Dzongkhag of Mongar and Trashigang. Out of four locations, three were fenced using FEF at village level and one was fenced at individual household farm. One of the village level fencing was done at Muktangkhar under Bartsam Geog in Trashigang, and second village was in the same geog was Nalung (see Table 1).

Table 1. Fabricated electric fencing site information

Location	A	B	C	D	E
Phosrong, Mongar	1	1.5	6	1	June, 2006
Muktangkhar Bartsam, Trashigang	19	5 .2	87	3	June, 2009
Ngalung, Bartsam, Trashigang	19	8 .3	100	4	May, 2010
Banangree, Drepong geog, Mongar	28	12 .3	150	7	June, 2010
Total	67	27.3	343	15	

A = number of beneficiary households, B= Total length of fence (km), C = Total agriculture land protected (acres), D= Number of energizer installed, E = Date of establishment

Table 2. Crops grown at the FEF sites

Crop	Muktangkhar (n=19)	Nalung (n=17)	Drepong (n=17)	Phosrong (n=1)
Maize	x	x	x	x
Upland	x	x	x	
Potato	x	x	x	
Peanuts	x	x		
Vegetables	x	x	x	x
Fox tail			x	

n= number of participants

The former had been fenced as a whole village since 2009 and later since 2010. The farmers of those villages had been growing maize and upland rice as main cereals crops; they also grew potatoes, peanuts, along with some vegetables and fruits as cash crops (Table 2).

The data collection was done by using focused group discussions that revolves around the effectiveness of the FEF on the selected impact indicators shown in Table 3. The effectiveness of those impact indicators were compared before and after the fencing on the same field. The effectiveness of FEF against the nuisance animals (commonly crop raiding animals) was evaluated using scoring method. The common agreement on the score was drawn through hand rising of the participants of the focused group members.

Table 3. Impact indicators used to evaluate the effectiveness of FEF and their corresponding measuring unit

Impact indicators	Measuring unit
Crops damaged or protected	%
Cultivation area (increase or decrease)	%
Fallow land (increase or decrease)	%
Household food security	%
Crop diversity (increase or decrease)	%
Households in Agriculture	%
Crop protection measures	%
Time for farming activities	%
Time for social and cultural life in village	%
Time for child care	%
Community mobilization	Nominal
People movement into village (in Migration)	%
Household disputes	%

Other parameters such as safety of FEF to humans as well as animals, management and maintenance arrangement of the device were collected from focused group discussions and through individual respondents. For the cost effectiveness, a cost comparison between FEF implemented by RNR-RDC Wengkhar and commercial electric solar fencing promoted by DoFPs was done.

3. Result and Discussion

3.1 Effectiveness of FEF on socio-economic parameters

Before the introduction of FEF, the crop lost to wildlife (Figure 1) was as high as 55% in Drepong and was more than 40 % in all the villages with known mitigations measures such as crop guarding, scare crows, fencing with bared wire, stone walls, etc. However, the scenario changed after the introduction of FEF, the crops lost to wildlife was less than 10 percent in all the studied villages

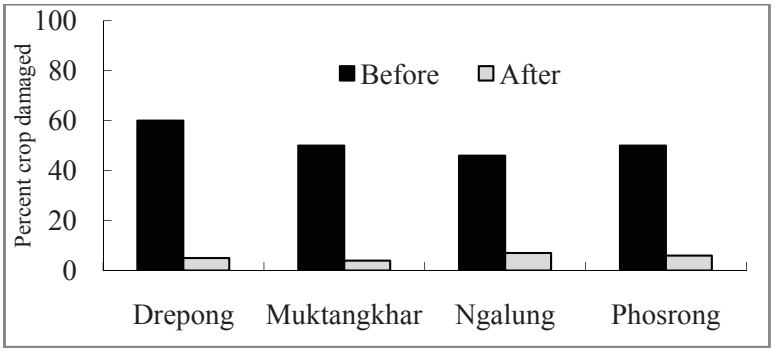

Figure 1. Impact of FEF on crop loss

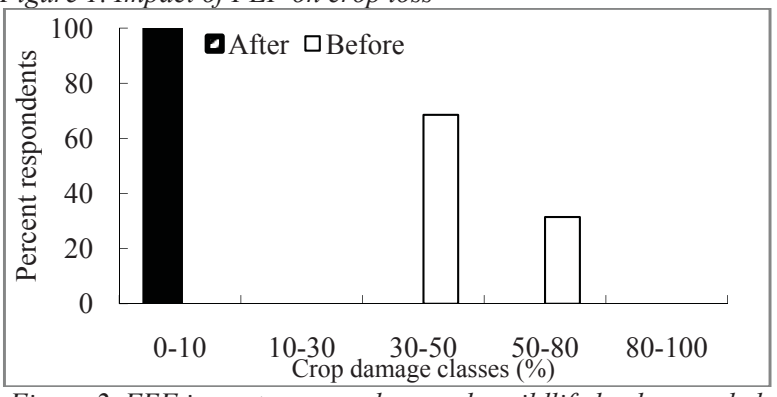

Figure 2. FEF impact on crop damage by wildlife by damaged classes.

The amount of damages was on higher scale ranging from 30-80 % before the fencing was introduced in the study area. However, such damages to crops by wild animals had declined to less than 10 percent (Figure 2). There was marked increased in area under cultivation in at least three study sites (one Phosrong not shown) after the establishment of FEF. In Drepong the fencing was indifferent to establishment of FEF (Figure 3).

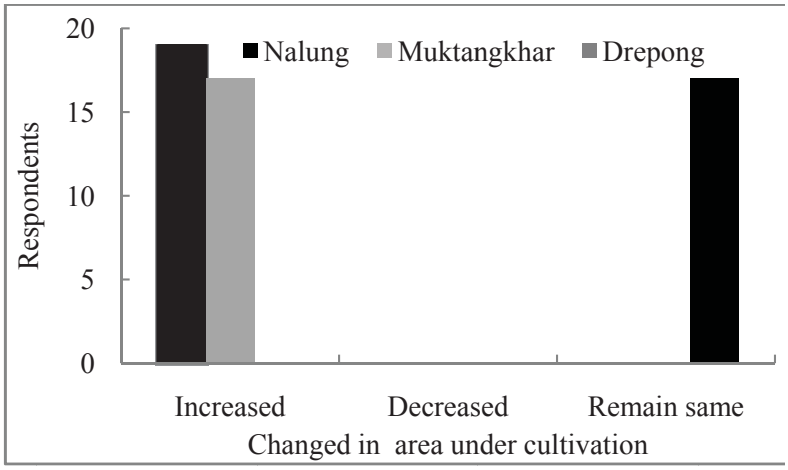

Figure 3. Impact of FEF on area bought under cultivation

Table 4. Impact of FEF on socio-economic indicators

Factor	% respondents		
	Increased	Decreased	No change
Household in agriculture	35 (n=19)	-	65(n=35)
Crop diversity	67 (n=36)	-	33(n=18)
Fallow land	69 (n=37)	-	31(n=17)
Farming time	100 (n=54)	-	-
Time for Socio-cultural life in the villages	100 (n=54)	-	-
Children caring time	100 (n=54)	-	-
Immigration	35 (n=19)	-	65(n=35)
Crop guarding time	-	100(n=54)	-

There were lots of changes in major socio-economics of farmers after the establishment of FEF across those study areas (Table 4). There was increase in number of households engaged in agriculture, farming time, and time for socio-cultural life in the villages, marked increased in caring time for children. Likewise there was increase in crop diversities in some

villages, especially in Muktangkhar and Nalung. In Nalung, immigration of people from other jobs to farming was reported (Data not shown), other villages reported no apparent changed in farming demography. Interestingly there was marked decreased in fallow land in the fenced villages (Table 4). 69 % of the respondents reported decreased in fallow land in their villages after the establishment of FEF while 31% of the respondents reported no change in land under cultivation (Table 4). Unanimously all the respondents agreed that there was 100 % time saving on crop guarding. Most of interviewed farmers said, after the establishment of FEF, most of them could have good sleeps and good family environment (data not shown) marked by less family disputes (Table 5) related to crops protection.

Table 5. Impact of FEF on family harmony

Household trend	% Respondents	
	Before	After
No dispute	0	100 (n=54)
Very frequent	100	0

There was remarkable change in food security situation in the FEF established area. Before the establishment of FEF, most of the farmers interviewed reported 30-50 % food insufficient (Table 6) and they supplement the insufficiency by buying food from the market. They have reported that people opted for off-farm activities in order to meet the food deficits. However, after the establishment of FEF the food security situation had improved (Table 6). The import of household food was less than 30% in Nalung, less than 10% in Muktangkhar and Drepong. Interestingly, a famer in Phosrong could even sell surplus food products in Mongar.

Table 6. Impact of FEF on food security of farming households

Village	Food security classes (%)											
	Self sufficient+ surplus production sold (1)		< 10% of food bought (2)		<30% of food bought (3)		30-50% of food bought (4)		50-70% of food bought (5)		>70% of the food bought (6)	
	B	A	B	A	B	A	B	A	B	A	B	A
Nalung	-	-	-		-	x	x	-	-	-	-	-
Muktangkhar	-	-	-	x	-	-	x	-	-	-	-	-
Drepong	-	-	-	x	-	-	x	-	-	-	-	-
Phosrong	-	x	-	-	-	-	x	-	-	-	-	-

X indicates average values

FEF was not only effective towards enhancement of several socio-economics parameters but also effective on enhancing and fostering relationships at the community level. One of such socio-economic parameter was community mobilization on regular maintenance of the fence. About 68% of the respondents (Table 7) reported that it was difficult to mobilize community for any work that would required collective efforts of all the people from the village, however, after the establishment of FEF in the villages, the scenario have changed from difficult to easy to achieve the collective efforts to undertake any activities (Table 7). It clearly showed the multiple benefits that the farmers were able to derive from the installations of FEF.

Table 7. Impact of FEF on Community mobilization

Community mobilizing factor	% Respondents	
	Before	After
No change	33(n=18)	2 (n=1)
Enhanced	-	31(n=17)
Difficult	66(n=36)	-
Easy	-	66(n=36)

Effectiveness of FEF against animals

Amongst wild animals the most nuisance crop raider was said to be wild boar in all the studied villages, followed by monkeys, barking deer and porcupines. The FEF was most effective defense against all most all the crop raiding animals (Table 8) except for porcupine. The FEF found effective for domesticated animals as well. The beneficiaries of the FEF reported that the fencing system was positively effective even against predators such as leopard and wild cats (Table 8).

Table 8. Effectiveness of FEF against crop raiding wild animals

Animals	Very low	Low	Moderate	High	Very high
Wild boar	-	-	-	-	X
Barking deer	-	-	-	-	X
Monkey	-	-	X	-	-
Porcupine	-	X	-	-	-
Predator animals	-	-	-	X	-
Domesticated animals	-	-	-	-	X

X denotes the percent scores were ranked for all studied area

3.2 Safety of the energizer to humans and animals

One of the concerns related to FEF is the concern regarding safety to humans and animals, both domestic and wild. For that matter, several indirect and direct interviews were conducted with the focused groups as well as individuals regarding the safety of FEF. The results are consolidated in Table 9. There were no single fatalities of humans or animals by FEF reported so far in the studied villages.

Table 9. Information on safety concerns of the FEF

Safety observation	Respondents	
Any observations of animals casualties since installation of FEF	Yes	No
	0	54
Any complaints of human casualties since installation of FEF	0	54

Cost effectiveness of FEF against standard commercial solar electric fencing

There were lots of positive benefits of FEF on different socio-economic parameters in all the studied villages were shown previously. However, whether it was also cost effective in terms of its affordability to the farming communities remained unresolved. In order to get insight of the cost parameters, total estimated cost of installing one km FEF based on 2010 cost is presented (Table 10) and also the cost comparisons between FEF implemented by RDC Wengkhar and a few selected fully commercial solar based electric fencing implemented by Department of Forest and Park services in southern Dzongkhags was done and presented in Table 11.

Table 10. Cost of installation of one km FEF 2010

Item	Rate(Nu)	Qty	Unit	Amount(Nu)
Fabricating Energizer	1700	1	-	1700
Fence wire (GI SWG 16) (Two strain of wire)	90	25	Kg	2250
HDPE pipe for pole insulator (pipe 32 mm diameter)	32	30	m	960
Iron Nails 3”	80	8	Kg	640
Wooden poles	10	33	-	320
Labour cost of installation	100	30	mandays	3000
Total cost/km				8870

Source: Penjor (2010)

The total cost (based on 2010 estimates) for fencing one km length of agricultural field using FEF was approximately Nu 8,870.00 (Table 10) whereas DoFPS commercial solar fencing was as high as Nu. 240125 (estimated from total length and total cost from Table 11) for the same length of fence. A total of 19km fenced was created with Nu. 168144.00 with FEF, whereas it cost DoFPS sum of Nu.5501270 for 22.91 km of fence (Table 11). In terms of cost the FEF is more cost-effective than commercial solar based fenced. The different types of available energizers are tabulated in Table 14. The cheapest according to market surveys remained locally fabricated installed with locally available materials for erecting fences followed by commercially produced energizer in combination with locally available materials. The most expensive ones were fully commercial energizer with commercial fencing materials (Table 12).

Table 11. Cost comparisons of installation of FEF TP Wengkhar and fully commercial solar based electric fencing implemented by DoFPs

TP_Wengkhar			DoFPS		
Location	Distance (Km)	Total cost (Nu)	location	Distance (Km)	Total cost(Nu)
Nalung	8.3	51211	Sipchu	10	651000
Muktangkhar	5.2	32084	Lamoizingkha	6.7	944308
Drepong	12.3	7589	Sengay	4.5	2,900000
Phosrong	1.5	9255	Dina Samtse	1.7	1005962
Total	27.3	168441	-	22.9	5501270
Average cost (Nu/km) 6170			240125		

Source: Wengkhar (2011) and DoFPS (2011)

Table 12. Types of electric fences and associated cost weights

Types of electric fenced	Cheap	Expensive	V/expensive
Locally fabricated energizer run with electricity with local materials as fencing materials	x	-	-
Commercial energizer run with electricity and full commercial fencing materials	-	x	-
Solar run energizer with local materials as fencing materials	-	-	-
Battery run energizer (Battery charged with electricity) with local materials as fencing materials		x	
Solar run energizer (fully commercial)	-	-	x

Source: Penjor (2011)

4. Discussion

Although the human wildlife conflict is one of the oldest conflicts, it is as old as existence of humans on the earth. There are several types of HWCs, in Bhutan such conflicts had been cause of concerns for all sections of society for decades. The most severe conflicts were damage to crops by crop raiding animals such as wild boars, monkeys and deer. For more than two decades Bhutanese farmers had lost more than 50 % of their crops to wild animals on yearly basis (DoA, 2010). These conflicts had impacted most of the socio-economic settings in the country side, the rural-urban migration was said to have its origin on HWC, the abandoned agriculture fields in the country side was directly or indirectly attributed to this conflict. For decades the Bhutanese farmers had been devising different mechanism to cope with the HWC. However, none of these coping mechanisms had been effective. Most mechanisms were labor intensive (guarding) or dangerous for living beings such as direct use of electric current from household outlets.

In recent years, the Ministry of Agriculture and Forests had been implementing multiple mechanisms to mitigate the HWC. One was creation of fund to compensate HWC victims and others were protection measures such as electric fencing. Since 2003, Department of Forests and Park Services had implemented solar electric fencing in southern Dzongkhags, however, the cost of those solar commercial fences were high (Table 11). In order to pave a middle path for effectively reducing the cost as well as giving optimum protection to crops against crop raiding wild animals, RDC Wengkhar fabricated energizers and were used on trial in two villages in Trashigang (Muktangkhar and Nalung) and one village (Drepong) and with a farmer in Phosrong under Mongar Dzongkhag. There were significant improvements of different socio-economic indicators after establishment of FEF in those villages. It is briefly discussed below.

The respondents reported that FEF was the most effective means to ward-off wild animals raiding their crops and saved more than 30% (on average) across the FEF established villages. There was positive impact on many aspects of village socio-economic parameters such as reduction of fallow land, in-migration of people to farming activities, time availability for caring home and children and for attending village cultural and social functions. There was marked decreased in frequency of household disputes. There was indication of increase in households in agricultural activities,

likewise the crop diversities reportedly increased in some villages. The FEF helped the famers to reduced imports of food items almost by 30 %.

Since crop raiding animals were common problem to everyone in the village and FEF provided avenue for fostering relationships. The constant maintenance requirement of the electrical fences for steady flow of pulses long the wires required certain commitment of work from the members. These commitments required routine maintenance of fences which required collective decisions from the members, ultimately there was fostering of relationship amongst users of the FEF. Ultimately, it paved way for community mobilization. One of the strengths of the FEF was community mobilization for common tasks, which may go long way fulfilling other requirements of farmers´ group. This approach was found to be most suitable in introducing the technology in the farms which have the merits of reducing the cost through cost sharing among the community members, enhancing cooperation amongst the members. In fact electrical fencing may be use as enhancer of farmers' group.

FEF was effective mitigation measures to most of the notorious crop raiders such as wild boars and deer. It was moderately effective against primates such as monkeys and other small animals such as porcupines. The group discussion reported that the extent of crop yield losses varied with the distance of agricultural field from forest boundary before the electrical fencing was introduced. The spatial distribution of total crop yield losses in any village indicated that they were highest in the area near to forest and least in the area near to village for all crops. Losses from areas near to forest contributed to more than 50% of total losses for each crop in all villages before the fencing was introduced.

FEF or commercial energizers installed using locally available fencing materials was found to be cheaper as compared to other types of electric fences for protection of crops. These combinations were almost 40 fold cheaper than commercial solar based electric fencing. The estimated cost of FEF was approximately Nu. 6170/km whereas solar electric fencing was Nu.240125.30/km.

The safety to human life was assured with FEF or commercial energizer (in combination with locally available materials and labor forces) as there were no reports of any case of deaths and injury to human beings,

wild animals and domestic animals so far. However, it should be noted that people with heart problems, pace-maker and repeated and continuous exposure to FEF may posed threat to human lives.

One of the major issues over success of FEF or electrical fencing was the collateral effect to the unfenced area. The unfenced communities reported increased crop loss to wild animals as wild animals seem to move to non fenced areas. Use of electricity may involve risks to lives. The FEF system involves use of electricity and hence, it involved safety concerns. Therefore, while installing and operating the FEF, cautions must be taken to ensure safety to humans.

5. Conclusion

There was a significant improvement in socio-economic conditions of people of three villages and a farmer in Eastern Bhutan, after the installation of the FEF. Most of the major socio-economic farm parameters were positive and farming activities and associated economics is found to be positive with FEF. The safety to human life and cost parameters were within the accepted norms. Weighing that FEF provided an optimum socio-economic benefits to farming community and could contribute to resolving the long standing HWC. The FEF or similar devices with affordable price could be adopted and tried as a crop protection device. However, proper procedures and standards should be followed. Further the study found that the electrical fencing is fairly recent intervention, more research on different installation techniques, designs and impacts on animals needs to be researched and it may be opted as one of the crop protection device.

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Impact of Lemon Grass Harvesting, Distillation and Marketing on the Livelihood of Poor Farmers in Eastern Bhutan

Dhanapati Dhungyel[18]

Abstract

Lemongrass grows naturally underneath the Chirpine forest and harvested, distilled and marketed by the farmers in eastern Bhutan since 1981. This study assesses the benefits and constraints of lemon grass industry to the farmers and understands the sustainability of resource base and suggests measures for sustainable management of lemon grass. Lemongrass industry has a direct benefit for the smallholders and subsistence farmers and is one of the main sources of off-farm income. It generates employment at the rural level and earns hard currency for the government. To further increase the cash income and reduce environmental impact from the lemongrass industry, development of management plan for long term sustainability of resource base, demarcation and lease of harvesting areas to the harvesters and, establishment of a suitable marketing channel & value addition is needed.

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*Keywords***:** Lemon Grass; Distillation unit; Lemon grass oil; Evaluation; Harvester; Distillers

1. Introduction

Lemongrass (*Cymbopogon flexuosus*) is a perennial grass which grows naturally in the wild under Chirpine forest in eastern Bhutan. It is used for the distillation of lemon grass oil which contains an essential oil known as "citral." Citral is of primary commercial value which has wide range of application in cosmetic, toiletry, perfumery, pharmaceutical and food industry. Lemon grass oil is highly valued in the international market and therefore is in considerable demand. Due to its high commercial value, the distillation of lemongrass oil was started in 1981 at Kurizampa in Mongar. It was first initiated by Bhutan Aromatic and Phyto-Chemicals

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(BAPC) of the Tashi Group of Companies. Initially, BAPC controlled the distillation. The farmers could only harvest and sell the lemon grass to BAPC. The firm thus had the major share of the benefits from the lemon grass. BAPC introduced the mild steel distillation unit which was also known as Tashi-type. This type of distillation unit produced poor quality oil which fetched low price in the international market.

Recognizing that the small farmers did not benefit much and that the oil production and quality was poor, the Ministry of Trade and Industry (MTI) intervened in the lemon grass oil distillation. MTI replaced the Tashi type distillation unit by improved stainless-steel distillation units, which greatly improved the distillation efficiency and quality of the oil. MTI also liberalized the harvesting and distillation of lemon grass to the farmers and organized into groups and supplied the distillation units to them. From 1993 onwards, it supported the marketing of lemon grass to Europe through the intervention from the Essential Oil Development Project.

This study looks into the benefits of the lemon grass harvesting and distillation to farmers after it was decentralized by the MTI. It also attempts to understand the opportunities and benefits derived by the subsistence farmers and the changes it brought in their livelihood.The main objectives of the study are to: assess the benefits and constraints of lemon grass industry to the farmers and communities and, understand the sustainability of resource base and recommend measures for sustainable management of lemon grass in eastern Bhutan.

2. Materials and Method

The target group for the study included farmers and distillers engaged in the harvesting and distillation of lemon grass oil in the four eastern *Dzongkhags* viz; Mongar, Trashigang, Trashi Yangtse and Lhuentse.

3. Result and Discussion

3.1 Lemongrass and its benefits to farmers

The estimated total area under lemongrass is about 50,000 hectares in the four eastern district of Mongar, Trashigang, Trashi Yangtse and Lhuentse. About 2/3 of Mongar surface area has lemon grass. Lemongrass grows naturally underneath the Chirpine forest in the eastern Dzongkhags.

Legally, the lemon grass growing in the wilderness is a Government property. The Government grants use right to communities who harvest lemongrass by paying a royalty fee of Nu.5/kg of oil. Lemon grass oil is scarce in the world market. There are only a few countries that produce lemon grass oil. The major lemongrass oil producing countries are; China, Indonesia, Guatemala and India. Recently, in the world market, the volume of oil traded has decreased from 2000-500 tons which attributed to decrease in the production and supply. In the last decade, however, the price of lemongrass oil has gone up from Nu. 407 to Nu. 600 depending upon the market demand. Organically-produced lemon grass oil fetches a premium price. The total annual production of lemon grass oil ranged from about 1,960 kg to 35,578 kg with monetary gains ranging from Nu 1.271 million to Nu. 12.446 million, respectively (Table 1).

Table 1. Lemon grass oil production and gross income

Year of Production	Quantity produced (Ton)	Income (Nu. in million)
1992	17.80	1.61
1993	6.70	1.27
1994	8.94	1.66
1995	19.57	3.87
1996	27.76	6.29
1997	19.58	4.82
1998	31.48	1.55
1999	35.57	12.44
2000	25.81	9.51
2001	21.32	8.70
2002	22.70	9.08
2003	13.71	5.64
2004	9.90	4.99
2005	10.55	5.31
2006	6.08	2.95
2007	7.05	3.42
2008	4.97	2.98
2009	1.96	1.17
2010	3.79	2.27

The communities benefited are small land holding farmers who mostly dwell in the vicinity of lemongrass growing areas. These farmers either operate as distillers or harvesters or firewood collectors. Majority of the distillers are mid level income farmers while the grass and firewood harvesters poor farmers. All lemongrass harvesters have an average land holding of 2.13 acres supporting a family size of 8 persons/household. Both men and women are engaged in lemon grass harvesting. Men take care of the distillation unit while harvesting of the grass is mostly carried out by women. The distillers and harvesters have no exclusive right over lemon grass.

Lemongrass oil distillation industry provides 900 to 1300 jobs in 72 days in a year or 64,800 to 93,600 person days in a year in four Eastern Dzongkhags. Lemongrass has proven to be one of the main sources of off-farm income for the farmers. It has been estimated that on an average each individual harvests 70.4 quintals of lemongrass per season and earn up to Nu. 2639.90. An analysis of income of farmers from different sources is given in the Table 2. From the different off-farm sources lemon grass contributes 30% of the total share of the income of the farmers. The additional benefits are: employment opportunities to 70.6% women folk (RNR-RC, 1998). Distillers make net profit ranging from Nu.20, 000 to 120,000 on an annual basis; current price fetches US$ 12.50/kg, and consistent support from the EODP in terms of technical assistance, logistics, quality control and marketing, and advisory services has helped farmers to earn cash income.

Table 2. Income by sources among villagers in lemongrass oil production

	Activity	Type of Income			
		Subsistence (%)	Cash (%)	Work share (%)	Income (%)
On-farm	Agriculture	59	41	34.9	40
	Livestock	55	45	33.5	20
	Timber	100	0	10.0	10
Off- farm	Lemon grass	0	100	12.3	30
	Weaving	100	-	3.7	1
	Wage labor	0	100	4.8	8
	Hiring of pack pony	0	100	0.7	1

Source: RNR-RC, 2005

3.2 Success Factors

The main success factors were the strong technical and financial support from the Government and United Nations Development Programme (UNDP). The government accorded high priority towards the development of the lemongrass industry as an enterprise for subsistence farmers. It provided the required human resource while the UNDP provided the funds to implement the project activities.

3.3 Assessment and improvisation of distillation technology

Four new types of distillation units were evaluated. This included the International Technical Assistance (ITA) type imported from the Netherlands; FAO unit without boiler; upgraded FAO unit with boiler and the Renewable Natural Resource (RNR) stainless steel. The old mild steel unit supplied by BAPC was closed due to poor oil recovery, production of low quality oil and high fuel wood consumption. ITA was introduced in 1990-91 from the Netherlands at a cost of Nu.1200000 and raw material requirement was in large quantities. The FAO unit without boiler was introduced at Nu. 54,000 but was found inefficient due to its short life span of 3-4 years. It was heavy and transportation from road point to the interior parts was difficult. The oil quality was poor and incurred a very high fuel wood consumption. FAO unit with a boiler was fabricated locally by developing a steam distillation system from locally available drums and was found quite efficient as it consumed 30% less fuel wood. The life span of the unit increased to 10 years. The average production increased substantially leading to significant increase in profit. Finally with the local innovation of the research team another distillation unit was fabricated and named the RNR unit. This unit was based on steam distillation technology and produced high quality oil with much greater efficiency. The unit was lighter and could be easily transported to remote areas. The cost of the unit was about Nu. 27,000.00, and was affordable to poor farmers (Legha, 1995). The oil recovery and the quality of oil were higher with an increase of 4% citral content as compared to FAO unit.

3.4 Lemongrass evaluation and management

In order to recommend the best essential oil producing species of lemon grass to farmers, different species were evaluated. Palmarosa (*Cymbopogon martinii* var. motia*),* curry leaf *(Murraya koenigii)* and *Mentha piperita* were evaluated for biomass and oil content. The result

indicated that *Cymbopogon martini* yielded 89.53 kg oil/ha/year while *Murraya koenigii* yield varied with location; *Mentha piperita* yielded 0.13% w/w. Harvest management studies of lemon grass under rain-fed condition in Mongar and Lingmethang indicated that dry matter accumulation was 36.81 and 29.52 tons while oil content was 0.24% w/w and 0.35% w/w, respectively. As lemongrass oil distillation was a new enterprise for the rural farmers, hands-on training on the distillation process and farmers organized into groups for marketing. Other activities include; setting up database, collect, test and preserve germplasm of essential oil bearing plants species, introduction and acclimatization of indigenous and exotic species, study on agronomy and management practices with respect to existing farming system and cropping pattern, effective marketing without the involvement of middlemen.

3.5 Constraints

Conflicts between harvesters and distillers-arise due to common property resource, unclear lemon grass harvesting boundaries and harvesters with no user rights. Anyone can harvest and as a result conflicts arise between households, villages and, harvesters of different geogs. Farmers suggest certain area be allotted for each distiller on lease so that there would be better management of resources. This would stop harvesters employed by one distillation unit from encroaching into other area and thereby reduce disputes among harvesters. Despite the effort to organize farmers into groups for better marketing and efficient harvesting, most operate as individuals. There is a need to organize distillers into groups to empower and improve their collective marketing and bargaining capacities.

Harvesters and distillers do not follow proper management practices – do not operate on demarcated area. Where lemongrass is repeatedly harvested, harvesters experienced less quantity of grass and number of cuts per season. Some harvesters have indicated that the decrease of forest fire incidence as one of the possible reason for decline of lemongrass. Farmers often see good growth of the pure lemongrass after forest fire. The new flush after the forest fire apparently gives higher oil recovery. However, frequent forest fire will, technically, not allow seed setting and seed dispersal for natural regeneration while more number of cuts a year will weaken the plant.

There is degradation of the resource base. The distillation units are placed along or near water sources (streams/springs) since a continuous flow of water is needed for distillation of lemongrass oil and for cooking

and drinking purpose as the distillers' family remains in the site along with their cattle. Apparently the lemongrass in the proximity of the water source and surrounding area are over harvested. When lemongrass is repeatedly cut and burnt its growth and biomass production tends to decline.

Invasion by exotic weeds (Parthenium and Lantana) is another cause of resource degradation. If not managed these weeds could soon suppress the lemon grass. Lack of adequate information on market is another constraint. Although lemongrass is widely sought after in the market, there is limited market information. Lack of rights of the farmers over resource base as lemon grass grows in the state forest; harvesters do not have any rights.

Strict legislation on forest fire and decline of lemon grass production. There is strong government legislation on forest fire due to its negative impact on the environment. Some harvesters have indicated that the decrease of forest fire as one of the possible reason for decline of lemongrass. Farmers often see good growth of the pure lemongrass after forest fire. The new flush after the forest fire apparently gives higher oil recovery.

4. Conclusion

Lemongrass industry has had a direct benefit for the smallholders and subsistence farmers of eastern Bhutan. It is one of the main sources of off-farm cash income. It generates employment at the rural level and earns hard currency for the government. To further increase the cash income and impact from the lemongrass industry the following recommendations are made; development of management plan for long term sustainability of resource base, demarcation and lease of harvesting areas to the harvesters and, establishment of a suitable marketing channel & value addition.

Acknowledgement

My sincere thank goes to the distillers, harvesters and firewood collectors of lemon grass industry in Mongar, Trashigang, Trashi Yangtse and Lhuentse for their valuable contribution. I am grateful to Dr Tayan Raj Gurung and Dr Mani Ram Moktan, CoRRB for comments and reviewing the manuscript.

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Cordyceps collectors and change in livelihood: need to balance with alpine ecosystem

Sangay Wangchuk[19], Nawang Norbu, Sherub Sherub

Abstract

Ophiocordyceps sinensis is an ascomycetes medical fungus with a long and illustrious history. This study was conducted in view of anecdotal reports of improving livelihood of collectors from its sale and concomitant damage to alpine ecosystem owing to increased collectors. This study quantifies the amount earned and contributions to livelihood of Bhutan's remote people living in the Cordyceps growing areas and identifies negative impacts from collection. The study was conducted through questionnaire surveys. 394 Cordyceps collectors from five Gewogs within Wangduephodrang and Bumthang were interviewed comprising of 60% of the collectors. We found that collectors earned about Ngultrum 57 million from 2004-2009 translating an average Nu. 23, 000 (US$ 460) per household per annum. More than 79% of the collectors use Rhododendron and Juniper wood for cooking and heating purpose. 96% of the collectors leave garbage while camping and collecting Cordyceps which is problematic. The extensive use of slow growing rhododendron and Juniper trees as fuelwood decimates the alpine forest. If left unregulated and unmonitored, the impacts from the collection of this highly priced fungi while improving livelihood will negatively impact the pristine alpine ecosystems from bad to worse.

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Key words: Cordyceps; Alpine Ecosystem; Fuelwood; Livelihood; Rhododendron

1. Introduction

Cordyceps sinensis is an ascomycetes medical fungus with a long and illustrious history. The genus Cordyceps is mostly entomophagous flask fungi belonging to the family Clavicipitacea (Winkler, 2008). According to recent DNA review of the genus Cordyceps, it was found that the DNA of *C. sinensis* was not the same as that of *C. militaris,* thus the change of genus to Ophiocordyceps was recommended within the newly recognized family

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Ophiocordycipitaceae (Sung et al., 2007; Cannon et al., 2009; Boesi and Cardi, 2009).

After the legalization of the harvesting of Cordyceps by the Royal Government of Bhutan in the year 2004, it has been harvested extensively in the alpine meadows of the country. Since the habitat of Cordyceps is in the high alpine areas of the national parks and near the border of Tibetan Autonomous Region of China, direct protection of the species has always been a great problem due to the inadequate number of forest personal in those areas, making it difficult to monitor unauthorized harvesting.Untill 2012, the highest price for Cordyceps in Bhutan was in 2007 was Nu. 522, 500.00 (US$ 10,450) for a kilogram at an auction in Dodena (Wangchuk, 2008). However in 2012 auction yard, the highest price for a kilogram of Cordyceps was Nu. 12, 20,000 (US$ 24,400) in Lunana (Wangchuk, 2012). Many observers believe that income obtained from the sale of Cordyceps is changing livelihood of alpine dwellers with significant impacts. Furthermore, it is likely that high intensity collection in the months of May and June, where the normally isolated and unpopulated alpine regions are subjected to huge influxes of collectors would bring significant ecological and environmental changes to the region. Our study assess: the impacts of increased income from the sale of Cordyceps on people's livelihood and; the negative impacts on the environment from the collection of Cordyceps.

2. Materials and Method

This study was undertaken through extensive interviews of Cordyceps collectors residing within two districts (*dzongkhags)* viz. Bumthang and Wangduephodrang. The two *dzongkhags* were selected for the study as majority of the cordyceps collectors are from these two *dzongkhags*. We randomly selected 60% of households who collect Cordyceps from five blocks (*gewogs*) within the dzongkhag of Chokor, Dangchu, Gangtey, Kazhi and Sephu within the two dzongkhags. The total number of households who collects Cordyceps was obtained from the village headman's (*Gup)* offices in-order to help us determine the number of households to be interviewed.

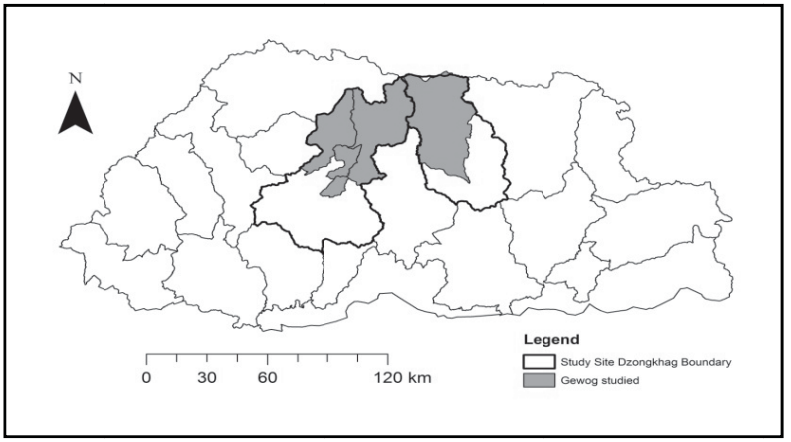

Figure 1. Map showing the study area

We classified the respondents as *Brokpas* and Non-*Brokpas* during the time of the interviews, where *Brokpas* were communities who did not practice intensive agriculture (essentially nomadic herders reliant on livestock) while Non-*Brokpas* are generally engaged in intensive agricultural farming activities.

Result and Discussion

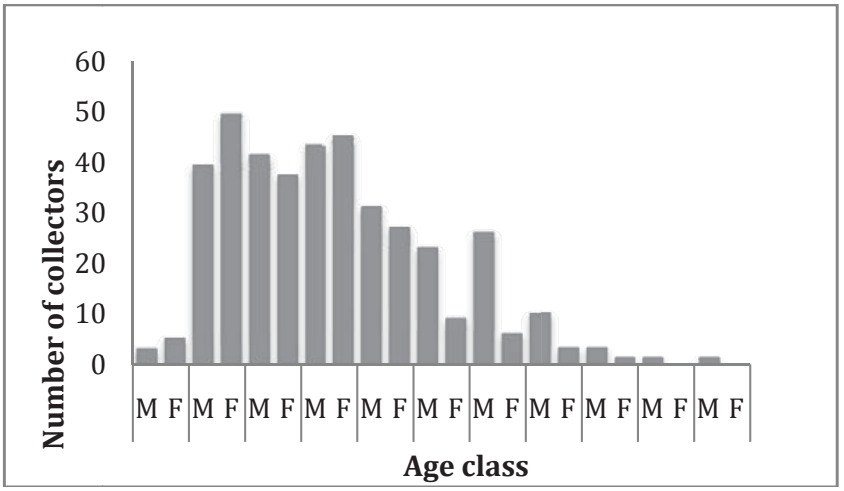

Figure 2. Household demography of Cordyceps collectors

2.1 Household demography

Out of 168 and 226 Cordyceps collectors interviewed from Bumthang and Wangduephodrang *Dzongkhag* respectively, majority of the

collectors are found within the age range of 16-35 years (Figure 2). It is interesting to note that there are more females than men within the age group of 16-35 years. However, female collectors decrease significantly after the age group of 42.

3.2 Income

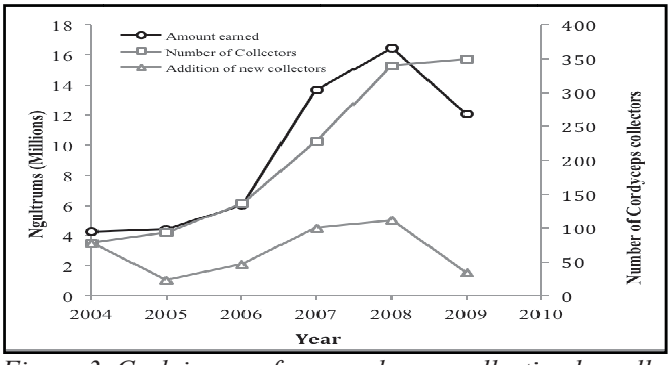

Figure 3. Cash income from cordyceps collection by collectors

Untill 2009, each household earned about Nu. 0.14 million (US$ 2800) since they started collection (provided each collectors interviewed collected without fail since 2004). Average annual income from the sale of Cordyceps is about Nu.23, 000 per household (US$ 460). In total, a sum of Nu 57 million has been earned from 2004 to 2009. Amount earned increases from 2004 to 2008 and drops in 2009 despite the increase in number of collectors. The reason may be because of the difference in the price for Cordyceps per kilogram in the market/auction yard. Till 2005, only one person from a household was allowed a permit to collect Cordyceps. This rule was amended in 2006 where every member of a household was allowed to collect Cordyceps. Then, in 2008, only 3 collectors from each household were issued a permit. This explains the rise in number of additional collectors after 2005 and the fall after 2008.

Brokpas earned (Nu. 0.22 million per household within the six years) more than Non-*Brokpas* (Nu. 0.15 million). This means that *Brokpas* earn about Nu. 34,000 per household per year while Non-*Brokpas* earn about Nu. 25,000 per household per year. This meager amount of money earned by the collectors does not seem to support many reports of earnings from Cordyceps significantly contributing to the improvement in living standards of collectors. This raises the question of how communities managed their livelihood before the legalization of Cordyceps harvesting.

Interviewees also claim that they build houses and supplement household purchases with earnings from Cordyceps. As such, the low-income figures obtained from interviews may be that they are not reporting earnings correctly. This could be because Cordyceps are being traded illegally.

3.3 Use of income

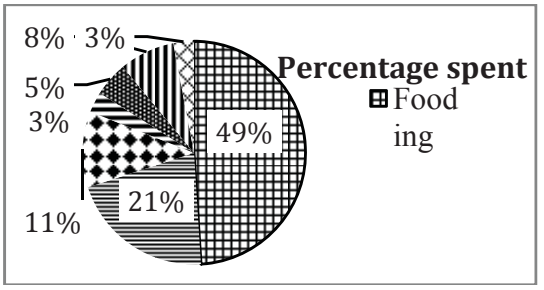

Figure 4. Percentage of income earned from Cordyceps and spent

93% of the Cordyceps collectors interviewed said that they collect Cordyceps for monetary gains, while 6% and 1% collect for family use and to give as gifts, respectively. 49% of these collectors who collect for monetary gains spend their earnings in procuring food items. About 21% of them use their earnings to repair or construct new houses and about 11% spend to continue their own education or to educate their children. We conclude that sale of Cordyceps contribute a major share of collector's annual income. Given that most of these are spent on purchase of food and household items, our findings highlight previously unidentified shortages of food or may even mean increased dependence on imported food items.

3.4 Degrading Shrub lands

In this study, we found that about 79% of the collectors interviewed use fuelwood (Rhododendron and Juniper) for heating and cooking purposes. Only 14% of the collectors used kerosene for their cooking purpose during the entire period of Cordyceps collection (Figure 5). Studies have shown that it takes nearly 169 years for *Rhododendron aeruginosum* to attain the "base" diameter of just 8 centimeters, with an annual increment of only about 0.6 millimeter (Wangchuk, 2011). The slow growth of Rhododendron coupled with huge extraction by the collectors in a big concern. It is however encouraging to note that the collectors themselves are aware of this problem. 5% of the collectors stressed that it should be made compulsory for everyone to stop burning wood and go for alternate

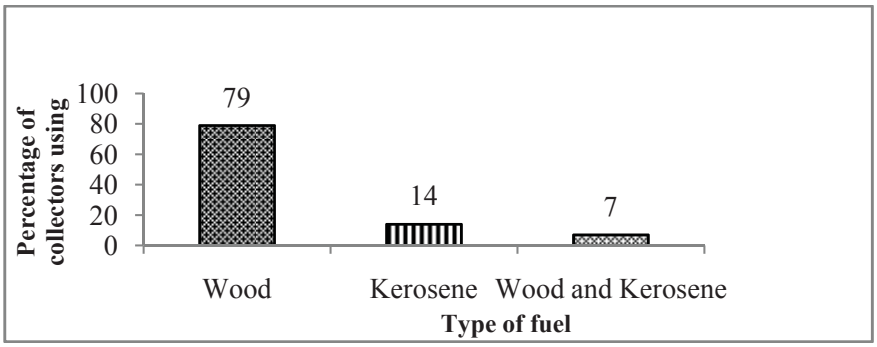

Figure 5. Various types of fuels used by Cordyceps collectors

Sources of energy including kerosene and Liquid Petroleum Gas. Fuelwood is scarce in the high altitude collection grounds, which are above tree line. The only available woods are Rhododendron, Dwarf Juniper and Willow, which are harvested extensively leading to opening of the areas in the fragile environment. Such openings may accelerate the process of mass wasting thereby leading to many ecological and environmental hazards.

Figure 6. Cordyceps collector transporting backload of Rhododendron for fuel

3.5 Littered Landscapes

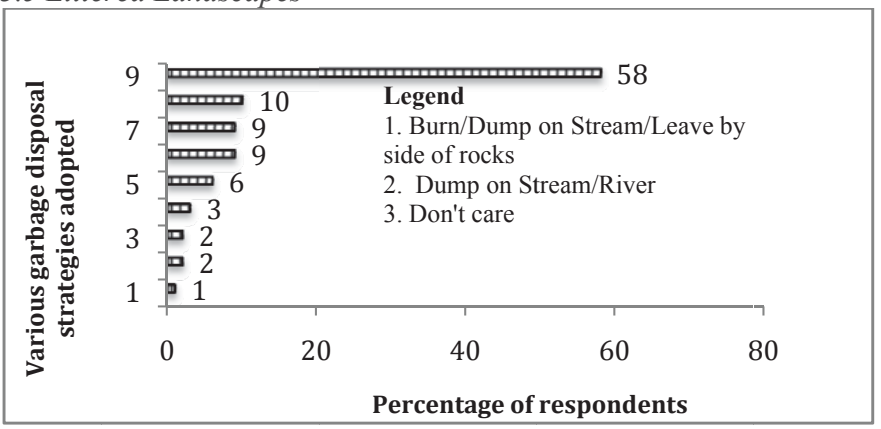

Figure 7. Garbage disposal strategies adopted by those collectors

Garbage management is also a serious concern in the Cordyceps collection areas. Garbage is mostly plastics and bottles. There are no proper garbage disposal strategies adopted in the collection areas and camping grounds. People throw garbage everywhere: both in the collection and camping ground as well as the routes leading to the collection site. Only about 4 % of the collectors interviewed take back the garbage with them and 96 % of them admit to not taking back the garbage while returning back home from the collection ground. Of the 96% who do not take back garbage, 58% dispose their waste either by the side of the rocks or underneath the rocks. About 9% claim to burn the waste, and only about 6% bury the garbage. About 3% of the collectors dump garbage in streams (Figure 7). This will be hazardous both to fresh water biodiversity as well as people living downstream. To tackle this problem, 28% of the collectors suggested the need of identifying proper garbage disposal site in the collection and camping sites. Few of them (about 2%) even suggested returning back to the collection site to clean the area after auctioning the Cordyceps. Some even suggested that temporary shops set up in the collection sites should not be allowed.

3.6 Changing Grasslands

Cordyceps collection season coincides with the time when young shoots of grasses start to come out. As such, the possible degradation of alpine grasslands is an important issue raised by the people of the area. They reasoned that increased number of people in their grazing area has lead to trampling of young grasses decreasing the quality of forage for their

yaks. Also about 16% of the collectors interviewed felt the need to seriously monitor collection grounds as some of the collectors were seen digging out Cordyceps, leading to the formation of holes. Digging out Cordyceps not only disturbs the grassland ecosystem but may also accelerate erosion.

3.7 Associated Forest Degradation

Income from the collection and sale of Cordyceps has also increased the purchasing power of the people. Apart from contributing to improved living standards of the collectors, the income made from Cordyceps has also been used to purchase power chainsaws. About 13% of the collectors purchased power chainsaws and the number is expected to increase with time. This may increase since they are able to supplement incomes from the use of chainsaws for converting wood to timber and fuelwood. With increasing chainsaw operators in the community and without proper understanding of felling techniques, we contend that forests will be harvested at increasing rates and may also lead to wastage of wood during conversion. The destruction is not only in the temperate belt of the country but even in the sub-alpine region of the country as *Brokpas* also buy chainsaws which is of immense use to them during the extraction of wooden shingles for roofing their houses.

Figure 8. Felled Juniper with chainsaw near tree line

3.8 Sustainability

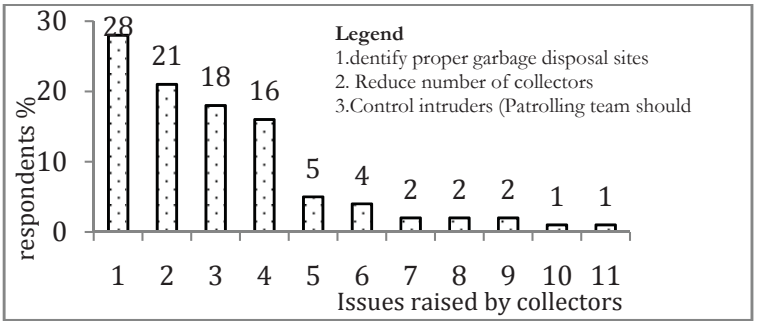

Figure 9. Prominent issues raised by collectors to address problems

With increasing number of Cordyceps collectors annually, sustainability of this resource is a great concern. When we raised the question of sustainability to collectors, some collectors did not show any concern. A statement to this effect is as such: "Cordyceps has been there since time immemorial and will continue in the future too". Such notion towards Cordyceps could mean that either the collectors are not concerned with sustainability or they are trying not to voice concern fearing the consequences of government policies banning its harvest in the future. Only few collectors (2%) expressed the need to introduce the system of allowing the collection of Cordyceps in alternate years.

3. Conclusion

The study highlights significant impacts on livelihoods from the sale of a highly valuable Cordyceps. Given that people spend a majority of their incomes to supplement food and household expenses, our findings bring to light previously unrecognized potential dietary and income shortages. The collections of Cordyceps on some of the last pristine alpine Himalayan landscapes are also bringing about negative changes to the ecosystem. The extensive use of slow growing rhododendron and Juniper as fuelwood poses the risk of such shrublands from getting decimated completely. Growing problems of litter further compounds this problem. As such, if left unregulated and unmonitored, the impacts from the collection of this highly priced fungi while helping improve livelihoods will leave some of the last pristine alpine ecosystems on this planet transformed for the worse. We feel that more research should be encouraged to understand the ecology of Cordyceps to determine its sustainability in times to come.

Acknowledgement

This study would not have been possible without the help of many people. We thank Mr. Tenzin and his team in Wangchuck Centennial Park for helping collect data. We would also like to thank Dr. Mani Ram Moktan for reviewing the manuscript. Thanks to all the interviewees who patiently agreed to spend time in answering our questions.

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Growth and Population of Yula Bamboo under different environmental condition in Bjoka, Zhemgang

Tshewang Dorji[20], Bhagat Suberi

Abstract

The conventional management system and its consequences on growth and population of Yula (Neomicrocalamus andropogonifolius) was studied in Bjoka under Zhemgang Dzongkhag. Focus group discussion and field survey using transect and sample plots were conducted for collection of qualitative and quantitative data. Comparative analysis with earlier researchers' findings revealed degradation of resource in the forest despite shift in forest management responsibilities in community forest. The culm growth characteristics; diameter, length of useful and internodes length were found significantly different amongst the culms growing on different aspects and sites. North and east facing slopes were found supporting better growth and development of Yula with longer harvestable internodes and preferable sites for plantation work.

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Keywords: Yula; clump, culms; regeneration; management; total length; useful length; internode length

1. Introduction

Untill today Bhutan has a record of 50 bamboo species (Tobgay, 2008) of which 21 species are reported to be found in Zhemgang Dzongkhag (MOA, 1997; Mortan et al., 2004). Yula is one amongst many bamboo species that is more valuable and support livelihood of people residing in rural areas like Kangpara, under Tashigang, Gongdu and Nagor under Mongar in the east and Bjoka under Zhemgang in central Bhutan. It is exclusively used for making unique bamboo handicrafts like Bangchung, Lakchung, Baikur, Palang and Tsezem. It is called Ringshu in sharchop and Langma in Nepali (Ibid, 1997). It belongs to the family poaceae under sub-tribe Recemobambusoideae (Dystriakova et al., 2003)

Cane and bamboo handicrafts making is an age old tradition in Bjoka and skills are passed down from parents to the younger generation. Around 97% percent of the people in the geog are engage in this activity (Dorji &

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Beek, 2006). Cash generated from crafting activity contributes to 66% of gross household income. However, growing commercial trade and substantial scale collection has depleted yula resource in village nearby forest leading to collection of it from distance area or other geog like Ngala (Moktan et al., 2004).

Realizing the problem of yula resource degradation, the collection areas were converted to community forest in the year 2007 to ensure proper management (CFMG, 2007). However, Meijboom et al (2008) mentioned that although long experience of use enabled local people gain enormous knowledge on management but, linking their knowledge to action is a challenging task for the user group members due to scarcity of resources over high demand for the products. The collection work is still done on competitive basis.

Harvesting is considered as a management option to stimulate better regeneration and prevent from drying due to flowering (Moktan et al., 2004). However, Hogorth and Franklin, 2008; Jha (2010) mentioned that regeneration depends on number of young culms in a clump. Bamboo species like Dendrocalamus himaltionii regenerate and grows better at 50% harvesting intensity. Conversely, it was observed that bamboo species like Bambusa arnhemica, complete removal of culms has no effect on shoot production in the following year. Vazquez-Lopez et al. (2004) also found that density of young culms highest in the clump where harvesting was done in the previous year.

Non-wood forest products have become a prominent feature only in 10^{th} five year plan (SFD, 2008) not much study was conducted to assess impact of traditional management system on yula resource. Therefore, in view of sustainable management of yula resource, the present study aims at acquiring information on consequences of overharvesting to regeneration growth of new culms and growth differences under different environmental conditions.

2. Materials and Method

2.1 Study area

Bjoka geog located in south eastern part of the Zhemgang Dzongkhag has total area of 195.66 km^2 (Moktan et al., 2004). It has total population around 2500 people, with 143 households (CFMG, 2007). The geog shares

its boundary with Silambi under Mongar Dzongkhag and Bardo under Zhemgang in the North, Gongdu under Mongar in the east, Ngala and Goshing under Zhemgang in the west, Norbugang and Dechheling under Pemagatshel in the south (Figure 1).

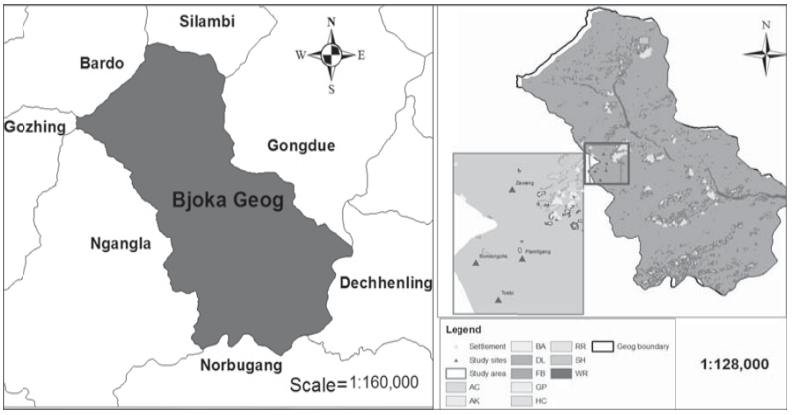

Figure 13. Map of Bjoka geog showing neighbouring geogs and study site

2.2 Data collection

Qualitative data were collected through focus group discussion held with committee members, informal talk during quantitative data collection work in the field and review available relevant literatures. Systematic sampling design of transect line and sample plots of 20 x 20 m were used for collection of quantitative data. The distance between transect was 100m with plot to plot distance of 50m. Total of 10 sample plot were laid alternately in each site. Data like number of clumps, culms (both live and death) length of total, useful and internodes and diameter of culms were collected by counting and measurement work. Lengths and diameter of culms were measured using measuring tape and diameter tape respectively. Other instruments clinometers, altimeter and GRS densiometer were used for measurement of slope and altitude and canopy closure. These were taken as important parameters to study distribution, growth and development to determine suitability site for plantation work in future.

2.3 Culms age determination

Based on physiological appearance culms age were determined. The culms were categorized into three groups- less than 1 year, 1-2 years and

more than two years. Less than one year old culms are the ones that are entirely covered by sheath and branch and leave development in progress. One to two years old culms are the one that have developed leaves and branches but dark green in colour. More than two years culms have many lateral branches developed and also mosses attached to it. Such classification was used by Tan, (2010).

3. Result and Discussion

3.1 Distribution, abundance and availability of Yula

Yula bamboo was found distributed between and altitude range of 945 to 1500 m asl although it was reported to be found growing as low as 250 m asl. Environmental factors like conopy closure, slope and altitude has influence on distribution and abundance and availability culms. Number of culms available for harvest is strongly correlated with number of clumps in sample plot. However, it has negative correlation is environmental factor like canopy closure, altitude and soil pH (Table 1).

Table 6. Correlation between yula clump distribution and availability of culms under different environmental conditions

	Study site	Clumps in plot	Culms in sample plot	Canopy closure	Slope (%)	Plot altitude	Soil pH
Study site	1	-0.46**	-0.05	0.19	-0.26	.93**	0.20
Clumps in plot	40	1	0.61**	-0.258	0.25	-0.53**	-0.34*
Culms in plot			1	-0.311	-0.02	-0.20	-0.18
Canopy (%)				1	0.12	0.31	0.17
Slope (%)					1	-0.29	-0.19
Plot altitude						1	0.20
Soil pH							1

*** Correlation is significant at the 0.01 level (2-tailed)*

** Correlation is significant at the 0.05 level (2-tailed)*

Density of clumps was highest in east facing slope and lowest in south facing slope (Table 2). However, availability of harvestable culms

was highest in north facing slope followed with south east, south and least in east. All in all density of clumps and harvestable culms (<1 year) in study area (4 acres converted to hectare) was 361 and 775 respectively. It is very much lower when compared to findings of 4350 clumps and 43585 culms per hectare in the same geog (Moktan et al., 2004). In the year 2007 it was found that the density was 947 clumps and 1157 clumps. Similar study conducted in Narphung under Samdrupjongkhar by Lhamtshok, (2009) reported clump density of 500 per hectare. The artisans expressed that the availability of yula has gone down as compared in the past. In places like Kamati and Dali, they deterred harvesting of yula from some of their collection area since 2011 onwards. The committee members from other villages also reported that there is decrease of 50% as compared to its availability in the past.

Table 7. Density of clumps and abundance of yula culms in study area

Sample	Clump	No.of culms/ha		
site	(Ha)	1<yr	1-2 yr	> 2 yr
Zawang	135	130	162	453
Borolongcho	95	235	90	335
Plamtigang	93	225	80	193
Toebi	38	165	65	147
Total	361	755	397	1128

3.2 Impact of present management system on yula

Although people in the area observed time bound harvesting (November to May) it cannot be guaranteed that management is sustainable as harvestings are done old fashion of competitive manner Meijboom et al (2008). Further, Non-adherence to harvesting rules like retention of young culms, cutting of culms above second or third internodes mentioned in management plan has led to degradation of resources in the forest. Nevertheless, field assessment discovered that cutting is must for regeneration of yula as maximum harvestable culms were found in a clump where harvesting was done last year. Further, regression test for casual relationship also revealed that relationship between number of live culms in clump and number of culms harvested in the previous year to regeneration of young culms in the following year was significant (r^2 =.779, p <. 05 and r^2 = . 594, p < .05). However, association was stronger with number of live

culms in clump with relationship size of 61% than with previous year harvest of 35 percent (Table 2)

Table 8. Regression to determine cause and effect of live and harvested culms to regeneration of young shoots

Variable	B	SE B	β
Total Live culms	0.501	0.034	0.779
Total harvested	0.669	0.079	0.594

a. Dependent Variable: < 1 year old culm
R^2 =.78 and 0.59,
P < .05

3.3 Population structure of yula culms

Nath (2010) stated that knowledge on population of bamboo is important for development of management approach to increase the production efficiency. In this study also population of yula culms of different age was enumerate in each study site to understand culms age composition of clumps. Number of culms per clump in study sites ranges from 3 to 19 numbers. Based on number last year harvested stump it was found that artisans harvested more than 80 percent of young culms from the clump. Such practices has led to clumps dominated by culms of older age (>2 years) that has effect to regeneration of young culms. Figure 2 shows the mean density of culms of different age in study area. Heavy harvest of culms added with improper cutting methods applied also led to dead of stump which has potential for sprouting new shoots.

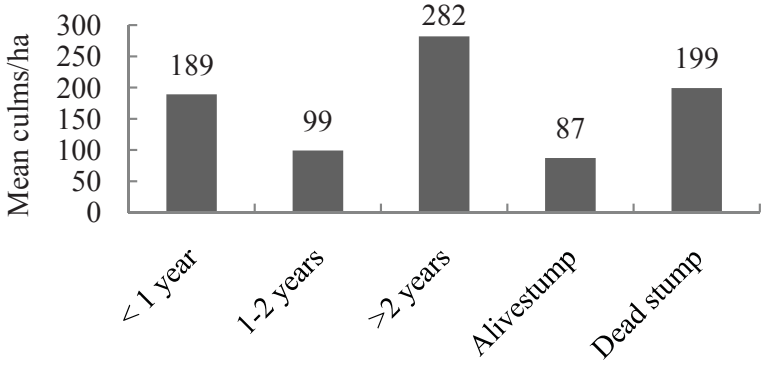

Figure 14. Mean population density of culms

3.4 New culms recruitment

Number of live culms and its condition has an effect on new culm production (Masiga et al, 2004 & Xaun, 2009). In 145 clumps investigated in four study sites (40 sample plots), it was found that 10% of clumps have not produced young culms for last three consecutive years and 21.47% for last two consecutive years. Figure 3 shows the percentage of clumps that have produced new culms in two consecutive years (2011 and 2012). In comparison it was found that there is significant increased availability of culms for harvest this year. On an average 78 % of clumps investigated have culms for harvest this year compared to 47.5 % in the previous year. This is due to turn for good shooting year. Although Toebi has 100% new culms recruitment but, number of harvestable culm was highest from Borolongcho as culms composition were better. Growths of young culms are determined by type of overhead canopy under which it grows.

3.5 Culm characteristics of yula

Here the culms characteristic refers to diameter, total, harvestable and internode length of individual of current year of <1 year old culms. One - way ANOVA and Post hoc test like Gabriel was conducted for multiple comparisons of mean and to find significant difference in culms characteristics.

3.6 Mean diameter

The mean diameter of culms in southern aspect was largest, (M = 1.55, SD = 0.65 cm) with maximum of 2.87 and minimum of 0.41 cm among the sites compared. Mean diameter of culms was smallest on south east facing slope, (M = 1.06, SD = 0.77cm) with maximum of 2.29 and minimum of 0.16 cm. Further, one-way ANOVA test also revealed that the difference of mean diameter of culms in different sites are significant, $F(3, 96) = 3.643$, $p < .05$.The post-hoc test like Gabriel conducted for multiple comparison of means at the significant of 0.05 level revealed that mean diameter of culms growing on southern aspect is significantly different from the south-east, $p = .019$ but not from the culms growing on other aspects. However, diameter of culms on south-east and northern aspect are in one homogenous subset and east and south are in another. Diameter of culms of northern aspect falls on both the sub-sets. Further, the mean plot also

proved that culms growing on southern aspect had the largest mean diameter followed with east, north and south-east (Figure 4).

On southern aspect most of the yula culms measured were growing under tall trees that have very large canopy. The finding confirms the statement made by Masiga et al. (2001) that bamboo culms growing under large tree canopy have bigger diameter. Further, (Wang et al. 2006) has explained that increased light led to maturation and self thinning of bamboo stands, resulting in fewer individuals of greater size. In contrast, (Jha, 2010) found that diameter of bamboo species like D. himaltonii and B. tulda was smaller on the culms growing on southern aspect. Diameter of yula culms was bigger at an altitudinal range of 945 to 1400m asl and then decreases with increase in evaluation. High organic matter content in soil supported diameter growth of yula culms although presence of tall trees with large canopy and high branching were found posing hindrance to growth of length. Diameters size of culms were similar (< 2 cm) as reported by Stapleton, (1994); Moktan et al. (2004); & Lhamtshok, (2009) indicating degradation at resource base.

3.7 Total and useful culm length

The total length refers to length of culms measured from base to top end. The north facing slope had longest total and useful length, (M = 8.82, SD = 1.28 m) with maximum of 12m and minimum of 6 m and (M = 5.41, SD = 1.31) with maximum of 8.0 m and minimum of 3.60 m and shortest in south facing slope (M = 4, SD = 0.82) with maximum of 5.30 and minimum of 2.40 m respectively. The shortest culms were observed in south facing slope, (M = 6.95, SD = 1.28 m) with maximum of 9.0 m and minimum 4.70 m and (M = 5.41, SD = 1.31) with maximum of 8.0 m and minimum of 3.60 m and shortest in south facing slope mean (M = 4, SD = 0.82) with maximum of 5.30 and minimum of 2.40 m respectively. It was found that there is significant difference in means total length of yula culms growing in different aspect, $F(3, 96) = 9.00$, $p < .05$ and mean of useful length $F(3, 96) = 8.60$, $p < .05$. Further, Post hoc test like Gabriel test conducted at significant level at 0.05 also showed that there is significant difference in total length of culms in each aspects among the site compared ($p < .05$; $p = 0.000$, 0.012 and 0.003) and ($P < .05$, $p = 0.000$, 0.016, 0.003). The mean plot of the total length showed that culms are longest in the slope facing north and shortest in the south (Figure 4). In general mean length of culms were shorter (14.3m) reported by Moktan et al. (2004).

Table 9. ANOVA showing significant of difference in useful length of culms in different sites

Source	DF	MS	F	P
Between Groups	3	10.76	8.605	0.000
Within Groups	96	1.251		
Total	99			

The clumps in Borolongcho have an average of 3-15 culms and 60% of it has more than five culms. Moreover, the area was under single canopy layer with canopy closure of 40% to 90% and 70% of sample plots had canopy closure of less than 80 percent. Further some trees in the area were evergreen and deciduous mixed which enables more sunlight to reach on the ground. Moreover, all matured culms in the sites were found climbed on trees and canopy was not dense. It was less exposed to sunlight during autumn and winter enabling to preserve more moisture for culms development. Masiga et al. (2001) also reported that tree shade have influence on internodal distance and culms height. He also mentioned that steeper slope tend to have taller bamboos and the statement is very much applicable to yula as longer culms are found on steeper slopes.

Taylor (2004) also mentioned that draft bamboos in china and Japan were grown taller under deciduous conifer tree. It was also further supported with Lhamtshok, (2009) stating that yula grows well under the tree canopy closure of 35 to 70 percent. Mesiga et al. (2001) mentioned that the length of bamboo clum is determined by number and length of internodes. For yula bamboo it was found that there is little association between these attributes. Other reason is that harvesting of culms from the site was restricted last year and could have more food reserve in rhizome as stated by Masiga et al. (2010) that younger culms have more capacity in reserving food than the older ones.

3.8 Internodes length of culm

Like other bamboo internodes of culms were shorter at based and at top. Average internodes length of culms were longest in the north facing slope, (M = 0.54, SD = 0.18 m) with maximum of 1.30 m and minimum of 0.40 m. Shortest internode was found in south facing slope, (M = 0.40, SD = 0.08 m) with maximum of 0.50 m and minimum of 0.20 m. There was significant difference in mean of internodal length of culms in different sites, $F(3, 110) = 4.79$, $p < 0.05$. Also, the Post-hoc test like Gabriel for

multiple comparisons was conducted at the significance of 0.05 level also revealed significant different, p = 0.009 and 0.006 indicating the differences in mean internodes length of culms. The mean plot showed that also on north and eastern aspects are longer than culms on other aspects (Figure 4).

Table 10. ANOVA significant differences in inter-node length of culms growing on different site

	DF	MS	F	P
Between Groups	3	0.12	4.785	0.000
Within Groups	110	0.025		
Total	113			

It was found that mean diameter was largest on culms growing on southern aspect followed with north, east and southeast. However, finding particularly on diameter was contradictory to report made by Jha, (2010) stating that for bamboo species like D. himaltonii and B. tulda diameter was largest on slope facing to north. In a research conducted on other bamboo it was also found that northern aspect have largest diameter when culms growing on different aspects are compared.

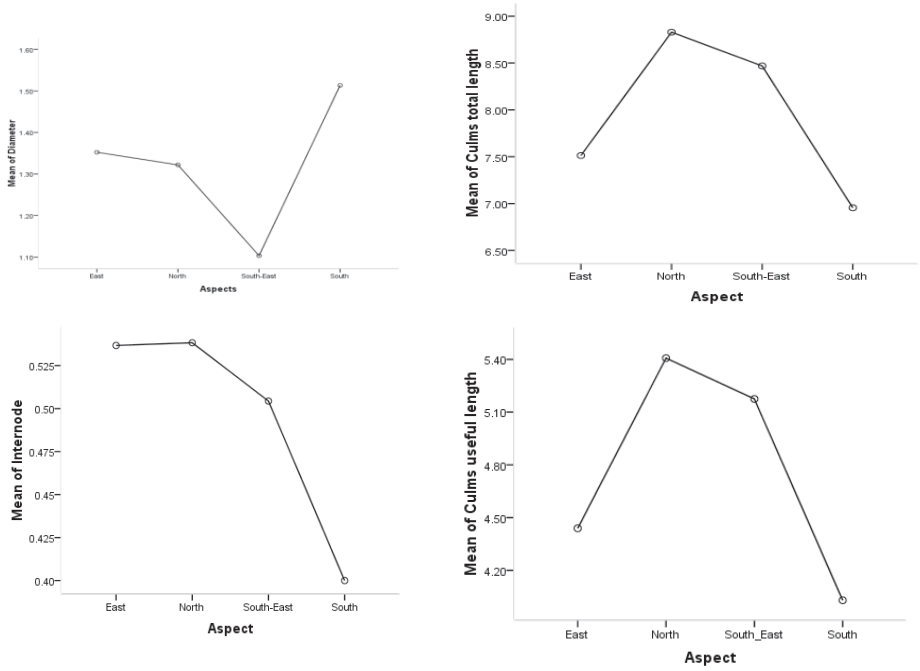

Figure 15. Diameter, total length, useful and internodes length of yula culms in different aspects

3.9 Morphology of yula

Culms are green shiny when young with only small hole. Later with aging it changes to dull green and serves as host for growth of mosses and lichens. Nodes have only one prominent ring. Culms less than one year of age were covered with sheath entire length. Sheaths were also present on internodes of older culms, but turned to dark or veins exposed. The similar findings were reported by earlier researchers like, Stapleton, 1994; & Moktan et al., 2004). Culms on north facing slope are softer than the culms from other aspect. *Branching:* By end of November to first week of December, branches develop on culms that are less than a year. It has one central dominant branch with 15-20 smaller branches around it (Figure 5). Such branching takes on upper part of culm. The newly sprouted branches serves as anchor in struggling over tree canopy and further produce shorter and thinner branches, and form sprays of leaves that can continue terminal growth to produce long curtains of foliage hanging from the tree branches (Figure 5). In absence of support, culms cannot withstand weight of newly developed branches and leaves and fall on ground.

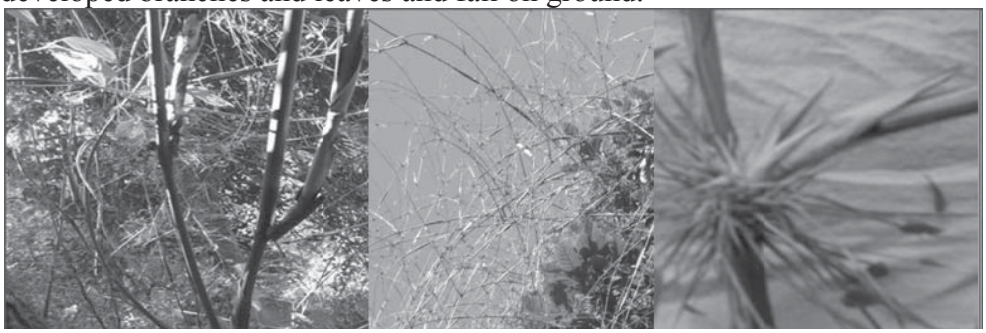

Figure 16. Branching pattern on yula culms

Lateral branches are also produced from viable buds present lower or mid part of culms which develop to the size of mother culm. It is locally called Abi-boleng (lateral branch sprouting from internodes at base of culms and climbs on trees). It also further produces strong central and smaller branches similar to mother culms. No smaller branches are developed around base of lateral branch. On a single culm maximum of four lateral branches were found. However, length was shorter than the ones coming from base of first mother culm. Yula have spreading branches, which are open and mainly confined on upper stem (Stapleton, 1994). Internodal length: Lengths of internodes are comparatively shorter at base and top portion than in middle. Further, yula culms crumbling over ground

have shorter internodes as compared to the ones climbing on trees. The length of internodes ranges from 0.30 m to 1.5 m (N = 250). Artisans believe that internodes from culms growing on northern aspect are softer than the ones growing on southern aspect. This is mainly due to the fact that culms in the area are less exposed to sunlight.

***Leaves**:* Leaves are 3.3 to 10.2 cm long (M = 8.9) and 0.6 to 1.5 cm wide (M = 1.6, N=103). Average leaves length of culms scrambling on ground have 6.1 cm long and 1.3 wide. Number of leaves on each branch ranges between two to eight with mostly having five. Flower: Although flowerings were reported in Bjoka, it was not available during the study period. Figure 6 is a specimen of yula flower collected from Gedu in February 2012. The flowers were found to have the following characteristics: spikelet and arranged linearly and measures between 8-20cm (Figure 6). In case of young culms (<1year old) flowers can be seen enclosed inside the sheath and panicles are longer than the exposed ones. Number of stamen from spikelet's ranges from 3-6 although Stapleton, (1994); Moktan et al (2004) and Lhamtshok, (2009) has generalized to six. Length of stamen was found to be 3-4 mm. Axis of the flowers sprouts from first or second node of leave branches.

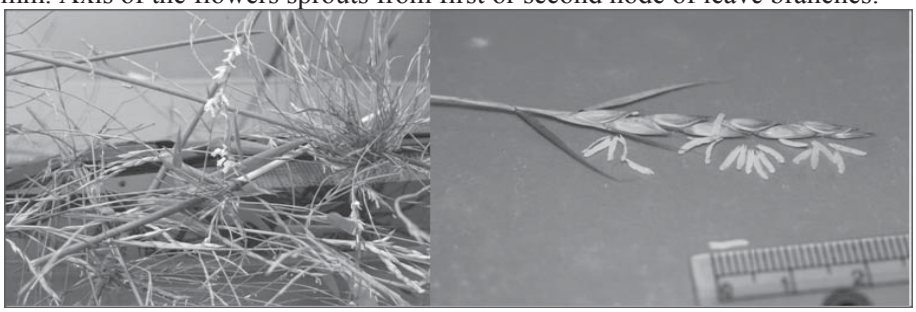

Figure 17. Yula flower with stamen hanging from spikelet

Sheath: Sheath length ranges between 15 to 63 cm with diameter of 2.54 to 7.62 cm with overlap of 1.27 cm (N = 57). However, both length and diameter are dependent on length of internodes. It has no auricles and hairs present and it was glabrous. Sheath present on older culms are darker than the ones on new culms.

4. Conclusion

Although the formation of cane and yula management group in Bjoka has impeded untimely collection of resources from the forest but, the management is conventional in nature. They harvest more than 80% of young culms and other management options like collection on rotational basis and removal of dead culms are seldom practiced. As handicrafts from

the geog has high demand their temptation to make more money results to careless cutting and collection of yula in competitive manner. In order to sustain yula resource in the forest, scientific management system needs to be initiated in the forest as well carry out plantation to increase its availability in future. For sustainable utilization of available, harvesting intensity should not exceed 50% as culms productivity depending on number of younger culms in a clump. Further, aspect also plays an important role in growth of yula. North facing slope was found most appropriate for plantation of yula.

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