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FOREWORD

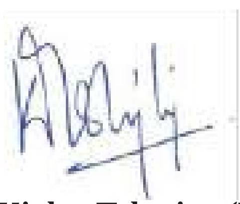
The Department of Agriculture is delighted to bring out the third volume of the Bhutanese Journal of Agriculture (BJA). BJA is a print and online open access English language journal on agriculture and publishes research articles annually with the primary purpose of providing an additional mechanism to disseminate appropriate technologies and knowledge and information in the agriculture sector.

The BJA strives to cover research findings that are innovative and relevant to sustainable agriculture development in Bhutan, and includes cross-cutting themes like postharvest, economics, agro-biodiversity, soil and water management, farming systems, pest and disease management and climate change.

Concerted efforts are underway in continuously improving the quality of the journal and we are glad and hope that with every passing issue we take our results a notch up, and come out with enhanced experiences. Our editorial team, comprising members entirely from within the Department of Agriculture, is pushing hard to conform to international standards. Registration for a DOI (digital object identifier) is in process and we are extremely pleased that a separate website for the journal has been launched last year that enables us to provide better access to its digital version.

The department takes pride in noting that the BJA has made significant inroads into not only motivating our researchers and field colleagues in sustaining a vibrant culture of research, but also in recognizing scientific communication as a key to success in research for agriculture development.

We thank the authors and the reviewers alike for their contribution. The BJA Editorial Board is commended for their added efforts and commitment in successfully taking out this edition.



Kinlay Tshering (Ms)
DIRECTOR

EDITORIAL

We are pleased to publish the third issue of the Bhutanese Journal of Agriculture (BJA). Our efforts continue to constantly improve the technical content, readability and scientific relevance of BJA for agricultural students, scientists, field and professional development workers. The BJA provides a platform for them to demonstrate their scientific work and build on the agricultural knowledge base. We are encouraged by the increasing number of article contributions; we could accommodate only 13 papers in this volume and the remaining manuscripts will be published in the ensuing issue.

In this issue, we have a wide range of technical papers from soil science, climate change impact, crop production, electric fencing, post-harvest management, agro-chemicals and effective micro-organisms. The paper on the soil loss prediction using Revised Universal Soil Loss Equation concluded that the erosion loss ranged from 5-150 ton/ha/year depending on the ground cover. A study on the assessment of soil fertility using soil nutrient index in three different land use systems was conducted, which will assist in determining nutrient management for crops. An assessment of soil nutrient status of mandarin orchard in Dagana recommended improving the level of carbon, nitrogen and potassium for higher productivity of mandarin fruit. In mushroom, a study on the spawn contamination of wood logs in Shiitake production identified *Scytalidium cuboidem* as the causal organism. The starch content in green maize cobs and subsequent product development was studied. It ranged from 209 g to 540 g in 3 kg of freshly harvested maize.

Evaluation of HDPE pipes as alternative to wooden poles in electric fencing suggested substantial saving in forest in the long run despite the higher initial investment of HDPE. An analysis of the government supported farm machinery custom hiring services was done to rationalize hiring rates and subsidy component. It suggested higher profit margin in using bigger farm machines such as tractors and combine harvesters. Green Super Rice (GSR) varieties, which have pyramided genes for tolerance to biotic and abiotic stresses combined with high yield potential, were evaluated in Samtenling and several good performers were identified. Another study on the impact of climate variability on rice productivity in Paro showed lack of awareness on climate change as the major obstacle for farmers and recommended capacity building on adaptation and mitigation measures.

In Quinoa, research on suitable sowing time under Samtenling agro-ecology identified mid-October to mid-Nov as the ideal sowing time. In post-harvest research, assessment of storage losses in maize in Chhukha, Dagana and Mongar indicated that insect damage ranged from 9-22% and the study recommended design and promotion of improved storage methods. The research on the effect of Effective Micro-Organism (EM) application and mulching on the yield of Japanese pole bean was inconclusive and recommended further research on the rate and method of application.We wish all our readers a happy reading of this issue of BJA!

Mahesh Ghimiray
EDITOR-IN-CHIEF

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Soil Loss Prediction Using Revised Universal Soil Loss Equation (RUSLE) for Amochhu Watershed in South-western Bhutan

Tsheten Dorji[a], Tashi Wangdi[a], Dawa Tashi[a], Karma Dema Dorji[a] Yeshey chedup[a]

ABSTRACT

Soil erosion by water is a serious problem all over the world affecting sustainability of agricultural production. In Bhutan, the limited productive land suffers risk from various forms of soil erosion. Although the soil erosion is common in all parts of Bhutan, it is not well quantified and documented. To generate information on soil loss, this study was conducted in Amochhu watershed using Revised Universal Soil Loss Equation (RUSLE). Geographic Information System (GIS) was exclusively used to generate factor maps of RUSLE. The factor maps include rainfall erosivity (R), soil erodibility (K), slope length and steepness (LS), Cover management (C), and conservation practice (P). A spatial distribution of soil erosion over Amochhu watershed was obtained by integrating all the factor maps in Arc GIS environment. The soil erosion was found to vary between 5 tons/ha/yr for well covered areas (forest) to more than 150 tons/ha/yr in steep-slope areas with sparse vegetation. The average soil erosion is 130 tons/ha/yr. The predicted amount of soil loss and its spatial distribution provides a strong basis for integrated management and sustainable land use for the watershed. It also gives clear picture as to where we need to focus our sustainable land management interventions. However, similar soil loss prediction study needs to be rolled out to other watersheds so that we have soil loss information at the national level.

Keywords: *Soil loss prediction, RUSLE, GIS, Amochhu Watershed, Bhutan*

1. Introduction

Bhutan is a small landlocked country with total land area of 38,394 km^2 in the Eastern Himalayas. It is located geographically between 26°47’N to 28°26’N latitudes and 88°52’ to 92°03’E longitudes with most of the mountain ranges running from north to south. Due to its rugged terrain, the country has only about 8% arable land (of which 2.93% is actually cultivated) and 70.46% (excluding 10.81% shrubs) under forest cover (NSSC, 2010). The predominantly steep slopes make land degradation a more serious threat in Bhutan than in most other places (Norbu et al., 2003). As per the study conducted by NSSC across the country, annually, about 3 to 21 t ha−1 of fertile topsoil is lost due to soil erosion (NSSC, 2010), which is a serious problem as mountain soils are generally defined as poorly developed, shallow, acidic and relatively infertile (Romeo et al., 2015). Loss of top soil significantly reduces the inherent soil fertility resulting in poor land productivity and crop yield. The land degradation, especially through soil

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erosion is thus becoming an important issue in Bhutan, because of its adverse impact on agronomic productivity, the environment, and consequently on food security and livelihoods.

In Bhutan, land degradation by landslides, soil erosion, internal biophysical and chemical deterioration is the main constraint for sustainable land use. It is caused by various interplay of factors such as anthropogenic factors (i.e. increased population, unsustainable land management practices, overgrazing, deforestation); bio- physical factors like unfavourable geology; and environmental factors viz. monsoon climate and the emerging effects of climate change observed through uncharacteristic patterns of weather conditions (Rinzin, 2008). There are other factors that do not trigger immediate attention like socio-economic changes and earthquakes in contributing to land degradation (Gyeltshen, 2010). The inclusion of the natural factors such as earthquake is crucial, especially in regions located in the seismically active zones, for instance in the Himalayan belt (Bali, Bhattacharya, & Singh, 2009), as one of the indirect factors causing physical land degradation, which is also confirmed through a series of physical land degradation assessments carried out in Bhutan (NSSC, 2013).

Notwithstanding the above facts, there is still no clear understanding about the extent of land degradation in Bhutan. This is mainly because of extreme diversity in agro-ecological zones, the relative inaccessibility of the country, the lack of reliable data (especially the latest satellite images) and the limited human capacity. Therefore, to help predict and build information on soil loss, this study was conducted in Amochhu watershed using the Revised Universal Soil Loss Equation (RUSLE).

2. **Materials & Method**

2.1. Site description

The Amochhu watershed is located between 26°47’N and 28°26’N latitudes and 88°52’ and 92°03’E longitudes (Figure 1). It covers an area of 88,929.53 hectares. Land use is mainly dominated by agriculture and the common crops grown are rice, cardamom, ginger, citrus, areca nut, maize, and vegetables. The communities also depend on livestock rearing for income generation mainly through sale of butter and cheese.

The sites fall within tropical to subtropical type of climatic zone with altitudes ranging from about 160 m to 2200 metres above sea level (masl). The sites vary in topography from nearly flat to very steep mountainous slopes. Precipitation is generally higher in the Central and Western Himalaya, due to the location close to the head of the Bay of Bengal. Although, screened from the full brunt of the monsoon by the Meghalaya hills in India, southern Bhutan still receives heavy and intense orographic rainfall, with annual means in the range 2.5-5 m (MoA, 1994). The rainfall data for the central and northern parts of the country show a decrease in precipitation recording with annual means precipitation of less than 1000 mm.

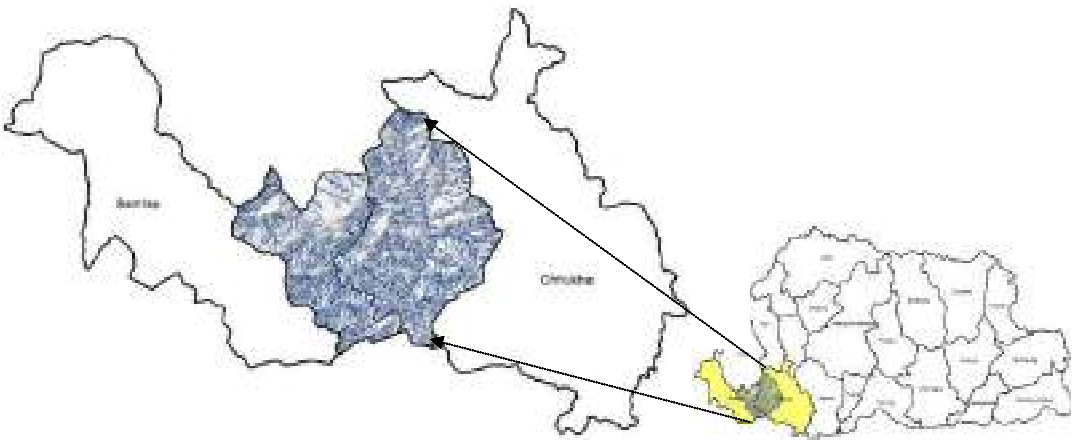

Figure 1. Map showing the location of Amochhu watershed

2.2 Information on rainfall, soil, land cover and DEM

For the Amochhu watershed, the annual soil loss rate was computed based on the RUSLE model in Geographic Information System (GIS) using Arc GIS 10.2.2 and its associated GIS packages. Annual soil loss is defined as the amount of soil lost in a specified time period over an area of land which has experienced net soil loss. It is expressed in units of mass per unit area, e.g. tons $ha^{-1}y^{-1}$ (Nearing, Lane, & Lopes, 1994)

Rainfall data from 1996 to 2011 was obtained from the National Centre for Hydrology and Meteorology (NCHM), Ministry of Economic Affairs (MoEA), Bhutan to compute the rainfall erosivity using the equation (2) developed by Renard and Freimund (1994).

Soil information, especially soil texture was determined by feel method during the 24 days fieldwork. 259 point data were collected for the purpose of interpolation using inverse distance weighted method (IDW).

Land use cover map obtained through digital image processing technique from ALOS images (AVNIR-2) of 2006-2009 winter seasons with 10 meters resolution was used to compute the **C** factor. Digital Elevation Model (DEM) with 90 m resolution obtained by SRTM, LANDSAT was used to generate the slope length and slope steepness.

2.3 RUSLE Model

The Universal Soil Loss Equation (USLE) (Wischmeier & Smith, 1978) was developed initially as a tool to assist soil conservationist in farm planning. It was widely used model in predicting soil erosion loss on specific slopes in specific fields. The USLE was extensively applied all over the world at many scales mainly due to the simplicity of the model formulation and easy availability of the data set (Wang et al., 2009; Pan, Zhang, & Zhao, 2005, Shi et al., 2004;

Bartsch, Van Miegroet, Boettinger, & Dobrowolski, 2002; Jain, Kumar, & Varghese, 2001; Jain & Kothyari, 2000). The Revised Universal Soil Loss Equation (RUSLE) was developed with the basic structure of the USLE with several improvements in determining factors (Renard & Freimund, 1994). The update was based on an extensive review of the USLE and its data base, analysis of data not previously included in the USLE, and theory describing fundamental hydrologic and erosion process.

The RUSLE quantifies the soil erosion as the product of five factors:

$$\mathbf{A = R \times K \times LS \times C \times P}$$

Where, **A** is the soil loss in tons per hectare, **R** is the rainfall **-** erosivity index, **K** is the soil erodibility index, **L** represents slope length, **S** is the slope steepness factor, **C** is the cover management, and **P** is the supporting practices factors.

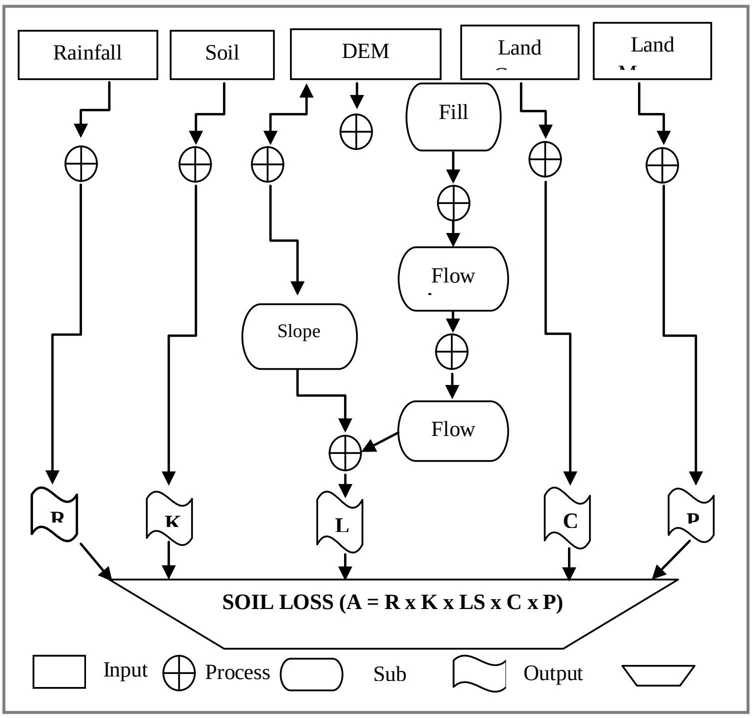

Figure 2. Flow chart of the methodology

2.3.1 Rainfall Erosivity Factor (R)

R factor is the quantitative expression of the erosivity of local average annual precipitation and runoff causing soil erosion. It is a measure of the erosive force of a specific rainfall. The greater the intensity and duration of the rain storm, the higher the erosion potential.

Since there is no record of rainfall intensity available with the NCHM for Amochhu watershed, the records of monthly rainfall data was used to determine the R factor. Rainfall data of 16 years average for four weather stations distributed over the watershed were used to calculate R values based on the equations of RUSLE and USLE developed by Renard and Freimund (1994). Equations are:

$$R = 0.0483 \text{ x } P^{1.61} \quad \text{for } P < 850 \text{ mm} \tag{1}$$

$$R = 587.8 - 1.219 \text{ x } P + 0.004105 \text{ x } P^{2} \quad \text{for } P > 850 \text{ mm} \tag{2}$$

Where ***R*** is the R-factor in RUSLE equation, ***P*** is the average annual precipitation.

Taking into consideration the average annual precipitation P < 850, the equation (1) was used to compute the R factor values.

Table 1. Rainfall Erosivity (R) values

Stations	Mean rainfall (mm)	R factor
Phuntsholing	334.81	560.90
Sipsu	465.28	952.73
Chukha	127.12	117.96
Haa	73.79	49.13

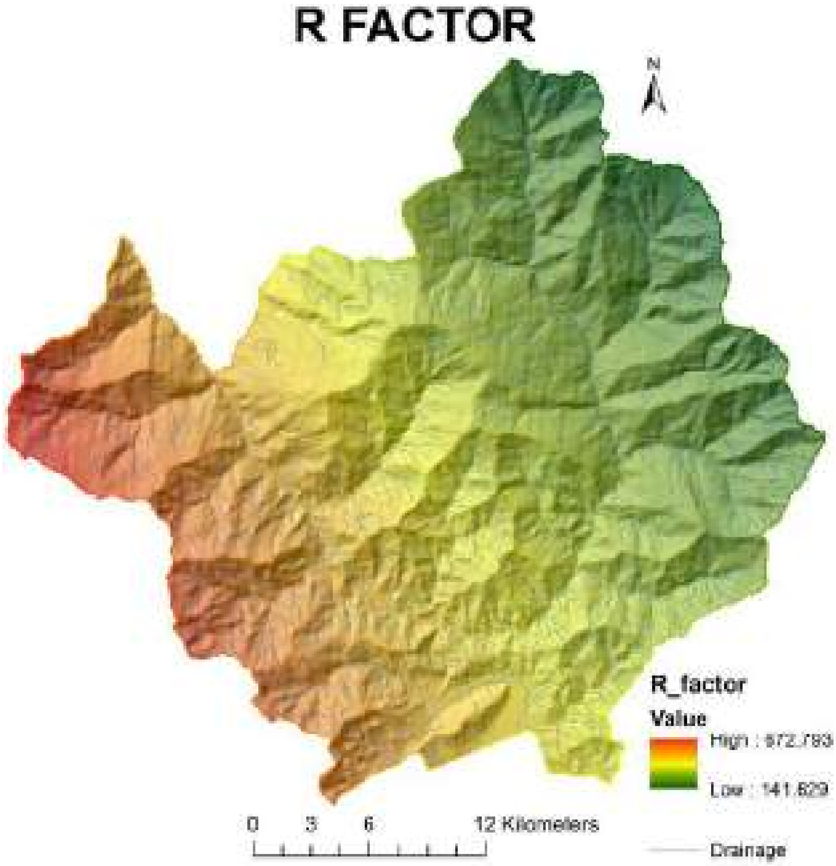

Figure 2. Map showing R factor

2.3.2 Soil Erodibility Factor (K)

The soil erodibility factor (K) is the average soil loss in tons/hectare (tons/ha) for a particular soil in the cultivated/or continuous fallow lands with selected slope length of 22.13 m and slope steepness of 9%. Texture is the principal factor affecting K, besides soil structure, organic matter and permeability. However, in the absence of soil map of Bhutan, only soil texture was considered.

The first step in soil erodibility (K) evaluations for USLE was the publication of K values for the runoff and erosion stations. Olsen and Wischmeier (1963) computed soil erodibility based on the new rainfall factor. Wischmeier and Mannering (1969) used a rainfall simulator in a study to measures soil loss on 55 Corn Belt soils. They computed soil erodibilities from the data adjusted to the unit plot. Then, they related soil erodibility to a number of variables using multiple regression techniques. A major finding was that very fine sand behaved much more like silt than like sand.

These data were further analyzed and used with the benchmark soil's erodibilities to develop a soil erodibility nomograph (Wischmeier, Johnson, & Cross, 1971) that has been proven as a good tool for estimating soil erodibility for most soils.

Basic data for estimating soil erodibility were collected from the field and a total of 259 soil texture points were captured using Global Positioning System (GPS) device. The data were then interpolated to generate soil texture of the unknown sites from the known points. Based on several literature reviews, the ordinary inverse distance weighted (IDW) method of interpolation was found to be appropriate to generate K factor map. The K factor values as proposed by Maiti (2013) based on the estimates using the published soil erodibility nomograph (Wischmeier & Smith 1978, Renard et al., 1996) was used for calculating K factor values as shown in Table 2.

Table 2. Soil Erodibility K values

Soil type	Erodibility	K value range
Fine-textured; high in clay	low	0.05 - 0.15
Course textured; sandy	low	0.05 - 0.20
Medium textured; loams	moderate	0.25 - 0.45
High silt content	high	0.45 - 0.65

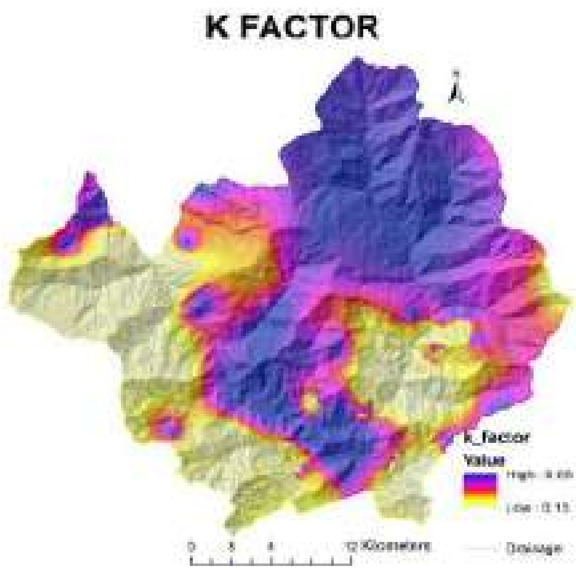

Figure 3. Map showing K factor

2.3.3 Slope Length and Slope Steepness Factor (LS)

The LS factor represents the effect of slope length (L) and slope steepness (S) on the erosion of a slope. The combination of the above factors gives the actual topographic factor. Thus, LS is the predicted ratio of soil loss per unit area from a field slope of 9% (5.16^o) on 22.1 m slope length. The Digital Elevation Model (DEM) with a resolution of 90 m was used to calculate L and S factors. The slopes were reclassified into 5 classes based on LS value distribution proposed by Hui et al., (2010).

The actual slope length is the horizontal distance (excludes slopes) of the plot being modeled and is converted to the slope length factor by the following equation (3)

$$L = \left(\frac{\lambda}{22.1}\right)^m \qquad (3)$$

Where λ is the actual slope length and m is the slope length exponent that is the ratio of rill to interill erosion.

The S factor (slope steepness factor) is the ratio of soil loss relatives to a 9 % slope, which is the standard slope that experiment plots use. The slope steepness factor is calculated as a function of slope as shown below:

$$S = 10.8\, Sin\, \Theta + 0.03, slope\ gradient \leq 9\ \% \qquad (4)$$

$$S = 16.8\, Sin\, \Theta + 0.50, slope\ gradient > 9\ \%$$

Where *S* is the slope factor, and Θ is the slope angle. Depending on the measures slope gradient, a different equation for *S* must be used. Choosing *S* allows the RUSLE to be more finely tuned for different terrains. This is important because the topographic factor and the RUSLE as a whole is very sensitive to the slope factor *S*.

In this study, LS is calculated by the USPED (Unit Stream Power Erosion and Deposition) method, which is using the raster calculation between flow accumulation and slope of watershed that can be done using Arc GIS.

In comparison to the RUSLE, the USPED is physically based model that incorporates a spatial component. In the RUSLE, L is dependent on linear distance λ_i, which is the horizontal length from the start of sediment transport to point *i* on the slope. Thus, they are inherently a single dimensional function. The USPED instead uses the area of upland contributing flow at distance *i*. In USPED, the area is substituted in place of the former slope length. The L calculation for point *i* on a slope is shown in Equation (5)

$$L = (m + 1)\left(\frac{\lambda_A}{22.1}\right)^m \qquad (5)$$

Where, L is the slope length factor at some point on the landscape, λ_A is the area of upland flow, *m* is an adjustable value depending on the soil's susceptibility to erosion, and 22.1 is the unit plot length.

The calculation of S value is shown in Equation (6)

$$S = \left(\frac{Sin\,(0.01745\ X\ \Theta_{deg})}{0.09}\right)^{n} \qquad (6)$$

Where, Θ is the slope in degree, 0.09 is the slope gradient constant, and *n* is an adjustable value depending on the soil's susceptibility to erosion. In this study, value m = 0.4 and n = 1.4, which is typically for farmland and rangeland with low susceptibility to rill erosion as mentioned by Pelton, Frazier & Picklingis (2014) based on Mitasova, Hofierka, Zlocha & Iversion (1996) was used. The slope (%) was derived from DEM and value of m was adapted from Wischmeier and Smith (1978) as shown in the Table 3. The result of the analysis is shown in Figure 5.

Using USPED method, the LS factor is calculated in the GIS Environment. The spatial analyst toolkit of the GIS software was used to generate raster layer of the slope gradient and hydrology toolkit to calculate flow direction and then flow accumulation. The output layer was used in the GIS raster calculator to generate LS factor map based on the following formula:

LS = Power ("Flow Acc"* resolution/22.1, 0.4) * Power (Sin ("Slope"*0.01745) / 0.09, 1.4) *1.4 and finally divided by 100 to convert to real LS factor following the formula: LS factor = LS/100

Table 3. M values

m-value	Slope (%)
0.5	> 5
0.4	3 – 5
0.3	1 – 3
0.2	< 1

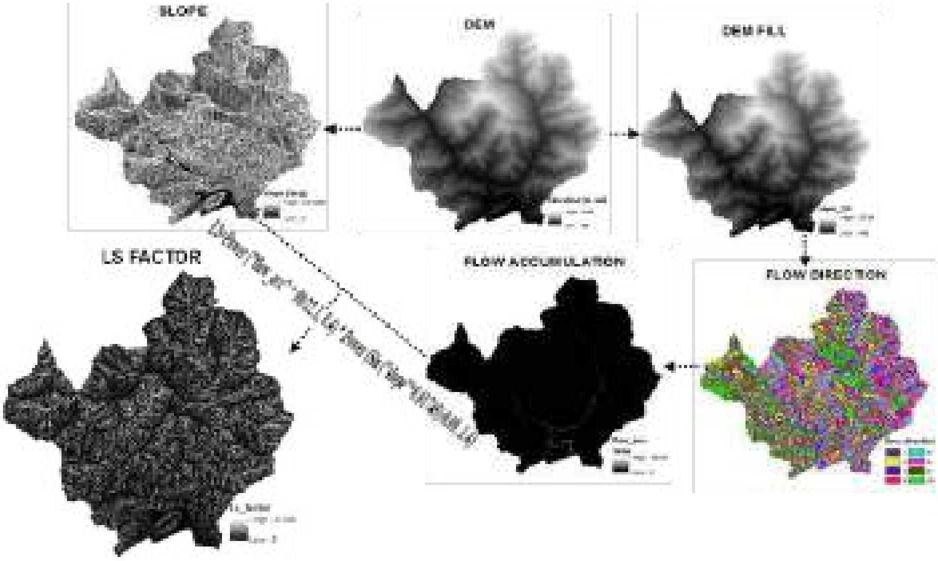

Figure 4. Map showing LS factor

2.3.4 Crop Management Factor (C)

During the land cover assessment in 2010, digital image processing technique was used. ALOS images (AVNIR-2) from the 2006-2009 winter seasons with 10 meter resolution, The Land Use Planning (LUP,1995) land cover maps, topography maps from the National Land Commission Secretariat (NLCS), LandSat (2004–2005) and image captured from Google Earth were used for the purpose of assessment.

Digital image processing was done in ERDAS platform. The images were first projected to DRUKREF–03 (Bhutan standard coordinated system, NLCS) to match the images with the existing topographic features such as contour and drainage lines.

The unsupervised classification was used to classify the images with the minimum of 30 classes with 10 iterations. Zonal Statistics function was used to summarize the values of a raster within the zones of another datasets. K means algorithm in R-Statistics was applied for grouping of homogenous segments. The initial assignment of land cover types was done by referring LUP (1995) land cover maps and the Google Earth prior to field verification. The minimum mapping unit was set at 500 m2.

Intensive field verification was done in almost all the gewogs for improving and validating the draft land cover maps. In order to ensure a reasonable level of precision, system accuracy assessments were carried out by comparing randomly selected referenced pixels. Random points were generated by the system with the minimum of 50 random points per class if the number of class is less than or equal to 12 and minimum of 75 to 100 random points per class if the total number of class is more than 12 at every geog level. The overall acceptance level of map accuracy was set at 85%. The Look up Tool in Arc GIS was used to reclassify the land use/cover map according to its C values (Table 4), which were assigned based on Hui et al. (1996). These values were used to reclassify the land cover map to obtain the C-factor map of the watershed.

Table 4. Crop Management C values

Category	C- factor
Agriculture	0.63
Built up area	0.003
Barren soil	1.00
Forest	0.003
Shrub	0.014
Grass	0.05
Water bodies	0.00

Table 5. Land use area

Sl.no	Name	Area (ha)	Area (%)
1	Agriculture	7993.27	8.99
2	Built up area	252.53	0.28
3	Barren soil	586.16	0.66
4	Forest	73231.11	82.35
5	Shrubs	4204.73	4.73
6	Grass	772.78	0.87
7	Water bodies	1888.95	2.12
Total		88929.53	100

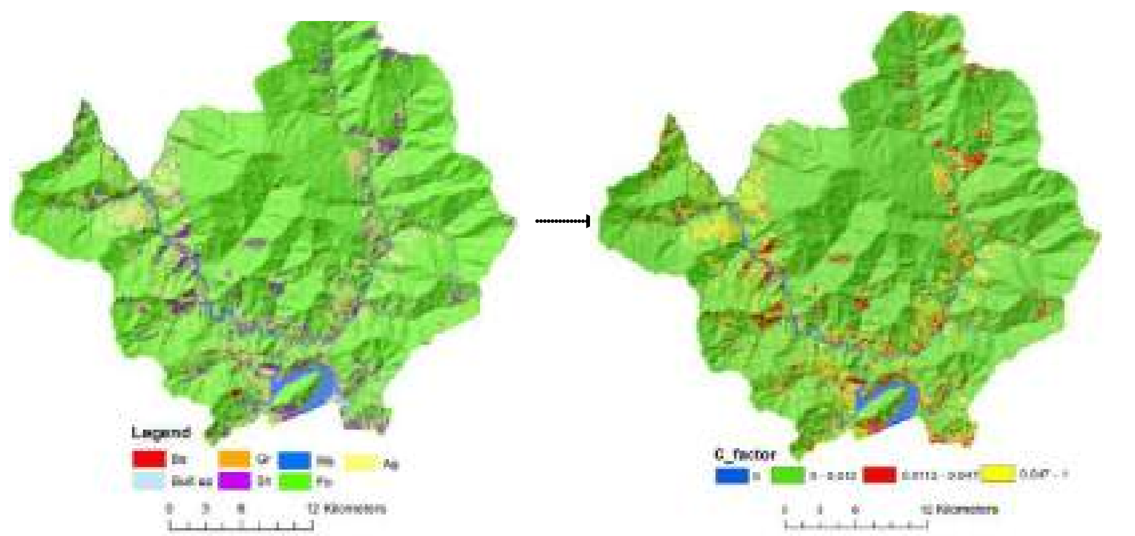

Figure 6. Map showing C factor

The land cover and management factor represents the effect of vegetation, management and erosion control practices on soil loss, the value of which ranges from 0 in water bodies to 1 in barren land.

2.3.5 Conservation Practice Factor (P)

The support practice factor P represents the effects of those practices such as contouring, strip cropping and terracing that help prevent soil from eroding by reducing the rate of water runoff. It is the ratio of soil loss with a specific support practice on croplands to the corresponding loss with slope-parallel tillage (Wischmeier & Smith 1978). The P factor map was derived from the land use/cover map and each value of P was assigned to each land use/cover type and slope as shown in Table 6. The Look up Tool in Arc GIS was used to reclassify the land use/cover and slope length maps according to its P value with contouring support practice.

Table 6. Support practice P (Shin, 1999)

Slope %	Contouring	Strip cropping	Terracing
0.0 – 7.0	0.55	0.27	0.10
7.0 – 11.3	0.66	0.30	0.12
11.3 – 17.6	0.80	0.40	0.16
17.6 – 26.8	0.90	0.45	0.18
> 26.8	1.00	0.50	0.20

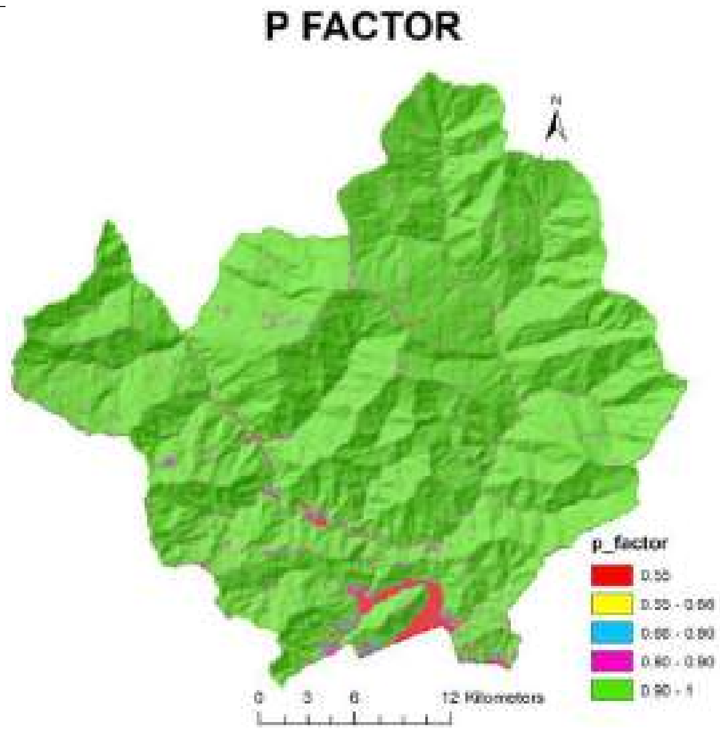

Figure 7. Map showing P factor

3. **Results and Discussion**

The data layers (factor maps) extracted for R, K, LS, C and P were integrated in the raster calculator option of the Arc GIS spatial analyst to quantify and generate the soil loss map of Amochhu watershed. The rainfall erosivity factors (R) of the four weather stations were found to be in the range of 142 and 673 $MJ \cdot mm \cdot ha^{-1} \cdot hr^{-1} \cdot year^{-1}$. The highest R value recording of 673 $MJ \cdot mm \cdot ha^{-1} \cdot hr^{-1} \cdot year^{-1}$ occurs in the lower part of the Amochhu watershed and the lowest value of 142 $MJ \cdot mm \cdot ha^{-1} \cdot hr^{-1} \cdot year^{-1}$ in the upper reaches of the watershed.

The K factor value for soil type obtained through literature review and based on Table 4 proposed by Maiti (2013) was used for K factor calculation. The erodibility of soils varies from 0.05 to 0.65 $ton.ha.hr^{-1} \cdot MJ^{-1} \cdot mm^{-1}$.The soil with the minimal erosion occurs in the lower reach of the watershed and the most erodible soils are distributed over the middle and the upper sections of the watershed.

The LS factor was calculated by using SRTM DEM with a resolution of 90 m. It is obvious from LS map that low LS value is distributed along the valleys in the lower part of the watershed. High S value occurs on the upper steeper slopes, suggesting the areas prone to erosion.

The map of C factor (Figure 6) was generated by reclassification of each land cover type using C values given in Table 4. From the table, a total of 82.35% is covered by forest, while agriculture covers 8.99%, barren soil 0.66%, grass 0.87%, shrub 4.73% and water bodies 2.12%. The C map of the watershed is mainly composed of values ranging between 0.01 and 0.70, respectively, for forest and barren soil. The higher C factor values indicate higher soil erosion potential as C factor is a ratio of soil loss in a cover management sequence to soil loss from the bare soil unit plot (Nyakatawa, Reddy, & Lemunyon, 2001).

The P factor map (Figure 7) was prepared from the spatial analysis program in GIS based on Table 6, which shows the relationship between P factor and slope levels for various land use types. The contouring support practice was considered in the present study based on the presence of hedge rows and terraces during the field work. The values of P factor of Amochhu watershed ranges from 0.55 to 1.0 with mean value of 0.78.

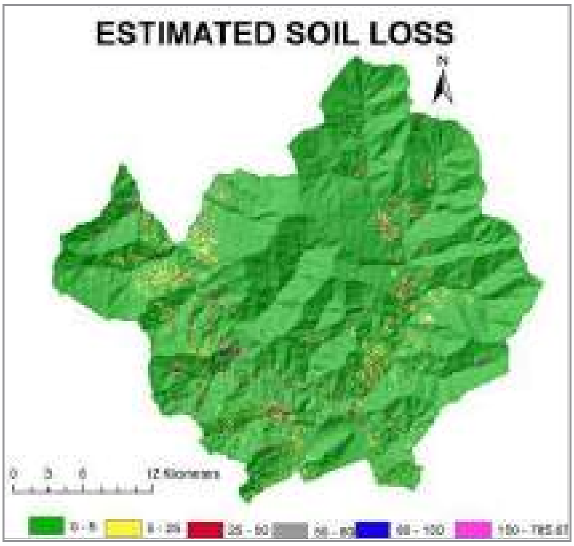

Figure 8. Estimated Soil loss map

Based on the analysis, the amount of soil loss in the Ammochhu watershed is about 5 tons/ha/year under forest, accounting for 93.41% area of the watershed. The predicted soil loss from agriculture land ranges from 5-25 tons/ha/year. The average soil loss from the watershed is about 130 tons/ha/year. The maximum soil erosion of above 150 tons/ha/year occurred on very steep section and accounts for 0.05% area of the watershed. The vegetated areas and the gently sloping sections of the watershed show least susceptible to soil erosion.

Table 7. Soil loss rate

Area (%)	Soil loss (tons/ha/yr)
93.41	5
4.22	25
1.57	50
0.50	80
0.25	150
0.05	> 150

4. **Conclusion**

Soil erosion caused by water is becoming a serious problem for Bhutan given its limited arable land, which is located on steep slopes. The main objective of this study was to generate soil loss information using the Revised Universal Soil Loss Equation (RUSLE) and Geographic Information System (GIS) for Amochhu watershed. The rainfall erosivity factor (R) ranged from 142 MJ mm ha/hr/year at the upper reaches of the watershed to 673 MJ mm ha/hr/year in the lower part of the watershed meaning that the erosion potential due to rainfall intensity is higher at the lower end of the watershed than the upper part. While the erodibility of soils (K) varied from 0.05 to 0.65 ton ha/hr/MJ/mm indicating that the minimum soil erosion occurs in the lower end of the watershed as compared to the upper reach. Similarly, the slope length and slope steepness (LS) factor was found low along the lower part of the watershed suggesting that the lower areas of the watershed are less prone to erosion as compared to the upper steep slopes.

The predicted amount of soil loss ranged from 5 tons ha/year under forest cover to 150 tons ha/year on very steep slopes and with less vegetation cover. Clearly the watershed areas with good vegetation cover and gentle slope are less susceptible to soil loss than the other areas with less or no ground cover and with steeper slopes. The predicted amount of soil loss and its spatial distribution, therefore, provides a strong basis for integrated management and sustainable land use for the watershed. It also gives clear picture as to where we need to focus our sustainable land management interventions. However, similar soil loss prediction needs to be rolled out to other watersheds so that we can have soil loss information at the national level.

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Spawn Contamination Causing Significant Impact on Wood Log Cultivation of Shiitake Production in Wangdiphodrang, Bhutan

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ABSTRACT

Significant damage was observed in billets of wood log cultivation of shiitake, Lentinula edodes, in 2018. Investigation of the damage was conducted to determine the cause through a case study in Wangdiphodrang, Bhutan in 2018. Mycelial colonization in the billets was investigated monthly from June to October, resulting in sample billets displaying poor mycelial colonization at a rate of 64.0±14.6 %. Monthly observations of spawn quality from March to October showed that poor quality spawn was present at a rate of 43.0±6.3 %. The primary contaminant was identified as Scytalidium cuboideum. An extremely strong correlation was detected between the rate of billets with poor mycelial colonization and the rate of contamination in spawn with S. cuboideum. Thus, it was concluded that the poor mycelial colonization in the billets was caused by spawn contaminated with S. cuboideum.

Keywords; Shiitake mushrooms, Wood log cultivation, Spawn contamination, *Scytalidium cuboideum, Lentinula edodes*

1. Introduction

Wood log cultivation of shiitake (*Lentinula edodes* (Berk.) Pegler (1976)) originated in China during the Sung Dynasty (Przbylowicz & Donoghue, 1988), and was followed by modern cultivation of shiitake with the invention of pure culture spawn in Japan (Kitajima, 1949; Mori, 1963). While the development and uptake of this method has spread quickly, many problems have been faced through contamination of spawn and improper treatment of billets. A historic event in the 1970's caused by infection of *Trichoderma harzianum* Rifai, (1969) resulted in damage amounting to Nu 1.875 billion (3 billion yen) (Furukawa & Nobuchi, 1986). While no other instances of such severe damage have been recorded since, in 2018, serious damage and significant loss of production caused by poor mycelial colonization in billets was observed in many farms in the western regions of Bhutan. Investigations into this damage through this case study conducted in the semi-highlands of Wangdiphodrang in 2018 suggest that the damage was caused by spawn contamination with the main contaminant being *Scytalidium cuboideum* (Sacc. & Ellis) Singer & Kang.

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Such serious damage caused by *S. cuboideum* in wood log cultivation of shiitake has not previously been reported, with only one small occurrence of this contaminant noted in Japan for the first time in 1995 (Uchida, Kuida, Uchiyama, & Udagawa, 1993). The purpose of this paper is to describe this unprecedented and historic incident observed impacting significantly on shiitake production in Bhutan with view to prevent such outbreaks again in the future.

2. Materials and Methods

The case study took place during the months of January to October 2018 in Kamichu, Wangdiphodrang (27.417, 89.898) at 1,425 m asl.

2.1. Wood logs and inoculation

Wood logs of *Quercus griffithii* Hook. f. & Thomson ex. Miq. were separated into three groups according to size, i.e., small logs (<8 cm in diameter), medium logs (8~12 cm) and large logs (>12 cm). The case study consisted of 50 logs per group, totalling 150 logs (hereafter, test logs). The test logs were inoculated with saw dust spawn and sealed with wax as per standard procedure on 24 and 25 January 2018.

2.2. Shed structure and water management of billets during incubation

After inoculation, test billets (hereafter, billets after inoculation) were incubated in a wooden shed. The 28×36 ft shed comprised of 3 windows and one door to allow for air flow. Gaps of ≈5mm were present between vertical wooden slats. Plastic sheeting was applied to the internal surface of the walls in a manner that allowed for rolling up or lowering of plastic to maintain required humidity and airflow. Following inoculation, test billets were stacked using different methods according to the size, i.e. small billets; a vertical bulk stack with the side of the bulk covered by a special plastic sheet with holes (Mikado Chemical M.F.G, Japan), medium billets; a dense crib stack (6 billets/stage) and large billets; a loose crib stack (3 billets/stage).

The plastic sheeting covering small billets was removed on 26 March, and on the same day, the plastic sheets applied on the wall were pulled down by 10cm to promote aeration. On 28 April, small billets were restacked into a dense crib stack. On 29 May, the sheets were pulled down again by 30 cm, the crib stack of small billets remained fenced with plastic sheets to prevent rapid drying. On 26 July, the plastic fence surrounding billets was removed and the sheets applied on the wall were again pulled down 90 cm. To prevent drying in small and medium billets, water was sprayed onto the floor twice weekly from July 26.Measurements taken on 27 August indicated that the weight loss (hereafter WL) increased to ca. 30 % and moisture content (hereafter MC) of sample billets had lowered to 32 %. Hence, soaking of the small test billets was conducted on 3 September for 14 hrs, and medium test billets on 14 October for 24 hrs.

2.3. Recording of ambient conditions in the incubation areas

To record temperature (°C) and humidity (RH, %), data loggers (ONDOTORI, TR-72nw-H, T&D Corporation, Japan) were placed at the centre of stacked areas for the small, the medium and the large test billets with data downloaded monthly.

2.4. Diameter, weight, MC and number of spawn inoculation points in test billets

All 150 test logs were measured for diameter and MC before inoculation. Moisture content was measured by inserting sensors of a wood MC analyser (MC-460, MK Scientific Inc. Germany) into the bark in the middle of each log. After inoculation, the number of spawn points inoculated per test billet were counted. The weight of each billet was measured monthly by use of an electronic balance with WL then calculated. The MC of test billets was measured using the method described below.

Moisture content was measured monthly from June to October. Five test billets were selected as sample billets per size group (i.e. a total of 15 sample billets/month). Wood disks (2-3cm width) were cut 20cm from each end of the sample billets, MC was then immediately measured in the middle of sap wood of the wood disk. The MC of a sample billet was calculated by averaging the MC of the two wood disks.

2.5. Mycelial colonization and evaluation method: ferric chloride and moist paper methods

Mycelial colonization in sample billets (n=75) was evaluated monthly from in June to October 2018. Each sample billet was cut into 3 pieces (a total of 45 sample pieces/monthly assessment). The three sample pieces were then split half along the line of the inoculated spawn.

Ferric chloride:

Half of each split sample piece was immediately sprayed with 5% solution of ferric chloride. Shiitake mycelium colonisation was observed and recorded in areas where tannins had been decomposed.

Moist paper method:

Half of the split sample pieces were wrapped with moistened newspaper then individually packed into a plastic bag and sealed with a rubber band. This was followed by incubation for 2 to 6 days at room temperature. Following incubation, mycelial colonization was evaluated into three grades using the criteria described below, with values in parenthesis being an evaluation score.

- Poor (1): Mycelia colonization covers<20 % of the vertical section of the sap wood
- Average (2): Mycelia colonization covers 20to 80% of the vertical section of the sap wood

- Good (3): Mycelia colonization covers >80 % of the vertical section of the sap wood

The mycelial colonization of a sample billet was expressed by the total scores of the three sample pieces. The sample billets were classified into three groups based on the criteria described below.

- Good：Totalevaluationscores of three sample pieces equal to 8 or 9.
- Average：Total evaluation scores of three sample pieces equal to 5, 6 or 7.
- Poor：Total evaluation score of three sample pieces equal to 3 or 4.

The percentage of billets classified in each category (Poor, Average and Good) was calculated by the following formula.

Equation 1.

Rate (%) =100 (number of classified sample billets /totalnumber of sample billets assessed)

2.6. Evaluation of spawn quality and spawn contamination

Spawn quality was observed every month from March to October using the same methods described in methods Section 2.5. After splitting, spawn appearance on the sample pieces was evaluated into three grades by the criteria described below.

- Good: Mycelia growth in a sap wood more than 30 mm from inoculation point.
- Average: Mycelia growth in a sap wood from 10 to 30 mm from inoculation point.
- Poor: Mycelia growth in a sap wood less than 10 mm from inoculation point.

The number of spawn in each category (Poor, Average, Good) from the 15 sample pieces were counted and expressed as percentage of the total.

2.7. Decomposition index

The decomposition index was approximately calculated using dry weight loss and the following formula. This is a close but approximate calculation as the dry weight of the sample also contains the dry weight of the mycelia.

Equation 2: $Y=100\ (DWa - DWb)/DWa$

Where, Y is a decomposition index, DWa is dry weight of substrate immediately after inoculation, and DWb is dry weight at arbitrary time of incubation. The formula was then mathematically transformed in which the index consists of two variables, i.e. increases in WL and MC of substrate (Watanabe, 1995).

Equation 3: Y=X1+ (B/a) X2

Where, Y is a decomposition index, X1 is an increase in WL, X2 is an increase in MC, B is wet weight of a billet at arbitrary time of incubation and a is dry weight of a billet immediately after inoculation.

2.8. Statistical analysis

The changes in MC (dry base) of billets between June, July and August were analysed using the multiple comparison method of Tukey (Bell Curve for EXCEL version 2.20) according to the size of billets.

2.9. Identification of contaminant

Identification of the spawn contaminant was completed as described in (Diplock, 2019).

3. Results

3.1. Property of test logs

Diameters, weights, MC and number of spawn per test log are shown in Table 1.

Table 1. Property of test billets before and after inoculation

Size	No. of billets	Diameter (cm)	Weight after inoculation (kg)	Mc before inoculation*	No. of spawn inoculated
Small	50	6.9±0.5	4.2±0.3	48.8±6.1	29.8±4.0
Medium	50	8.4±1.0	5.7±1.3	49.9±5.0	34.7±4.0
Large	50	13.6±1.5	14.9±2.8	50.4±3.8	48.8±6.0

Values show $\bar{x}$±SD, *MC before inoculation shows wet based MC

3.2. Ambient conditions during incubation

The ambient conditions in the stacked areas of small, medium and large billets recorded from 25 January to 25 October are shown in Figure 5. The temperature in the stacked areas of the three groups showed the same trend. In the stacked areas, the average humidity varied from 77.6 to 82.0 % during incubation and decreased in the order of small, medium and large groups.

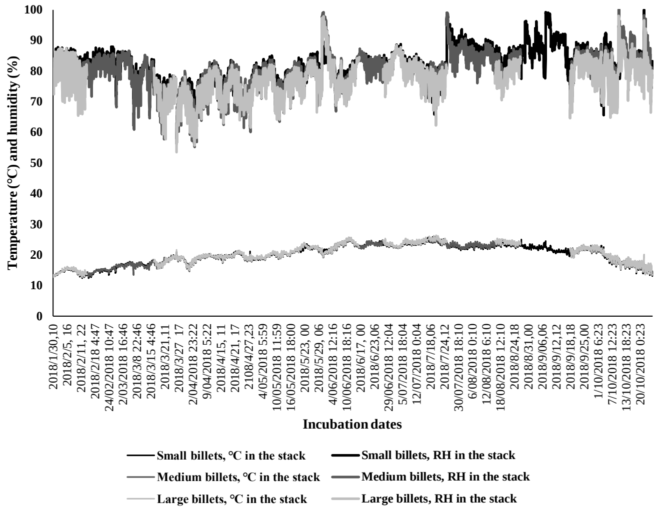

Figure 5. Changes in ambient conditions in billet stacks over the period of case study

3.3. Changes in WL and MC of billets

Changes in WL and MC of billets are shown in Figure 6 and Table 2 respectively. The WL of billets increased quickly as the diameter of billets reduced. The WL of three groups increased linearly until 27 August, this shows that the speed of WL was consistent within a size group throughout this period. On the other hand, MC was almost unchanged from April to July, with a rapid decrease in MC then observed in the three groups from July to August.

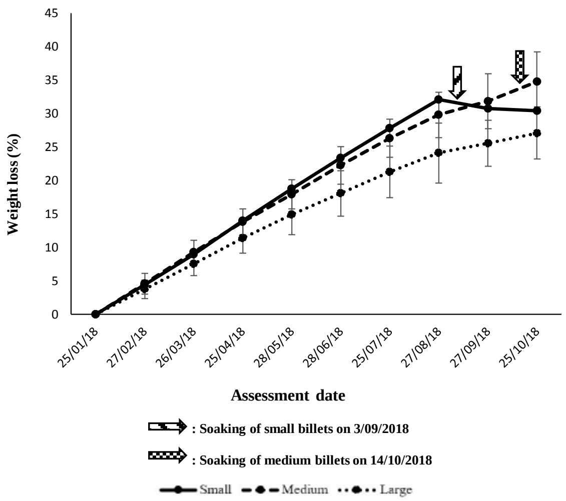

Figure 6. Weight loss of billetsover the period of the case study

Table 2: Average moisture content of sample billets from April-October

Date	Moisture content*		
	Small billets (n=5)	Medium billets(n=5)	Large billets (n=5)
25/04/18	43.2±9.0	39.4±3.8	42.2±9.4
28/05/18	42.1±11.6	42.2±10.4	43.7±5.7
28/06/18	42.5±4.9	45.0±4.3	44.3±2.6
25/07/18	39.3±11.6	41.7±7.8	46.7±8.9
27/08/18	31.5±4.0	32.1±12.7	39.8±14.8
27/09/18	35.6±20.3	29.5±6.7	38.0±5.5
25/10/18	43.2±19.0	32.6±19.0	35.6±15.5

Values show ±STD, *Moisture contentshows wet based MC

3.4. Evaluation of mycelial colonization in billets

The ratings of billets over time are shown in Table 3. The number of billets with poor mycelial colonization occurred at a rate of 64.0±14.6 % from June to October.

Table 3. Percentage of billets categorised in each rating score over time

Date	Categorised billets		
	Rating 3 (poor)	Rating 2 (average)	Rating 1 (good)
28 Jun. 2018 (n=15)	46.7	20.0	33.3
25 Jul. 2018 (n=15)	60.0	20.0	20.0
27 Aug. 2018 (n=15)	66.7	20.0	13.3
27 Sep. 2018 (n=15)	86.6	6.7	6.7
25 Oct. 2018 (n=15)	60.0	6.7	33.3

3.5. Evaluation of spawn quality and spawn contamination

The rating of spawn evaluated in three grades is shown in Table 4. The spawn from which mycelia did not grow more than 10 mm (Poor) was found at a rate of 43.0±6.3% from March to October. In addition, the occurrence of spawn evaluated as Average markedly decreased after June, but still existed at a rate of 9.6% in September and October.

Table 4. Percentage of spawn quality in each rating score over time

Date	Spawn rating		
	% Poor (<10mm)	% Average (10-30mm)	% Good (>30mm)
26 Mar. 2018 (n=114)	47.4	50.0	2.6
25 Apr. 2018 (n=103)	34.0	42.7	23.3
28 May 2018 (n=134)	44.0	35.1	20.9
28 Jun. 2018 (n=131)	38.9	11.5	49.6
25 Jul. 2018 (n=121)	44.6	11.6	43.8
27 Aug. 2018 (n=139)	41.0	27.3	31.7
27 Sep. 2018 (n=115)	54.8	9.6	35.6
25 Oct. 2018 (n=135)	39.3	9.6	51.1

3.6. Spawn contamination.

The moist paper method allowed for clear visualisation of spawn contamination (Figure 7). This contaminant was isolated and identified as *Scytalidium cuboideum (Diplock, 2019)*

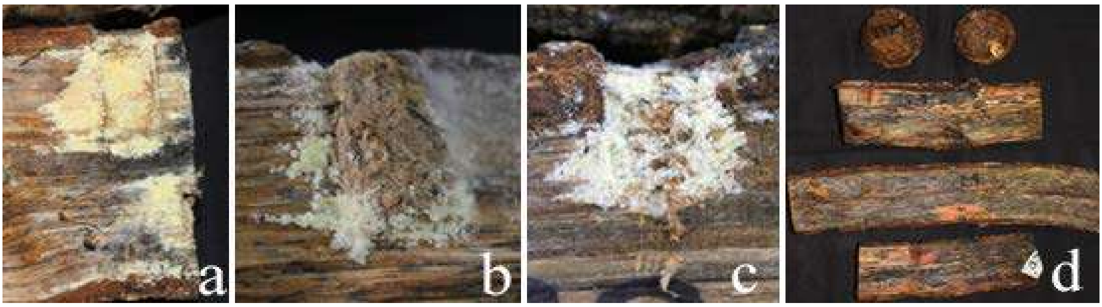

Figure 7. Symptoms of spawn contaminated with *Scytalidium cuboideum*. **a, b.** powdery yellow arthroconidia on spawn 31/7/18; **c.** powdery yellow arthroconidia on spawn 4/10/18; **d.** pink staining extending from spawn inoculation point 4/10/18.

Figure 8. **a.** Seven day old colony on PDA. **b.**Arthroconidia (×1,000) of *S. cuboideum*

Following treatment using the moist paper method, symptoms of *S.cuboideum* contamination in spawn were carefully observed, with the number of contaminated spawn recorded. These observations were to calculate the contamination rate (Table 5).

Table 5: Percentage of spawn observed as contaminated with *S.cuboideum*at each assessment date

Date of assessment	No. of spawn observed on 45 samples (15 billets)	Rate (%) of spawn contaminated with *s. Cuboideum*
28 Jun. 2018	131	51.9
25. Jul. 2018	121	64.5
27 Aug. 2018	139	77.0
27 Sep. 2018	115	87.6
25 Oct. 2018	135	68.9

4. Discussion

Weight loss and moisture contentare useful factors for indicating shiitake mycelial colonization in billets. Decomposition of substrate can be approximately expressed by dry weight loss (%) of substrate (hereafter, decomposition index).The formula

(Equation 3: Y=X1+ (B/a) X2) also can be used to compare the speed of decomposition between two periods, in this case, from June to July and July to August.

Figure 6 shows the linear increase in WL from June to July and July to August, indicating that X1is the same in the both periods. Whereas, Table 2 shows there was no significant difference in MC between the periods June to July in the 3 groups, however a significant decrease in MC was detected from July-August (small billets: P= 0.0112, medium billets: P=0.0233 and large billets: P=0.0477).This results in X2 being a larger negative number during the July to August period, indicating that the decomposition speed was lower during thisperiod compared to that of the period from June to July.

It would be expected that decomposition of billets progresses quickly from July to August, because of a greater increase in WL and a slight increase or no change in the MC through production of water during decomposition during shiitake colonisation. However, assessments on 28 August revealed that the MC of small, medium and large billets significantly decreased. It can be assumed that as the billet stacks were kept under appropriate ambient conditions, the low decomposition speeds were caused by poor mycelial colonization in billets (Figure 5). These findings indicate that unusual conditions were occurring in the billets.

The appearance of *S.cuboideum* in the moist paper method indicated shiitake mycelium growth had been severely inhibited by the presence of this contaminant. The same symptoms of shiitake inhibition have been recorded on billets of *Q. mongolica* var.*grosseserrata* (Blume) Rehd. et Wils, and identified as infection by *Scytalidium cuboideum* (previously classified as *Arthrographiscuboidea* (Sacc. & Ellis)) (Kang et al., 2010; Uchida et al., 1993).

When comparing the billets rated as 'Poor' (Rating 3) to the percentage of spawn contaminated with *S. cuboideum*, a very strong correlation is observed (r=0.9681)

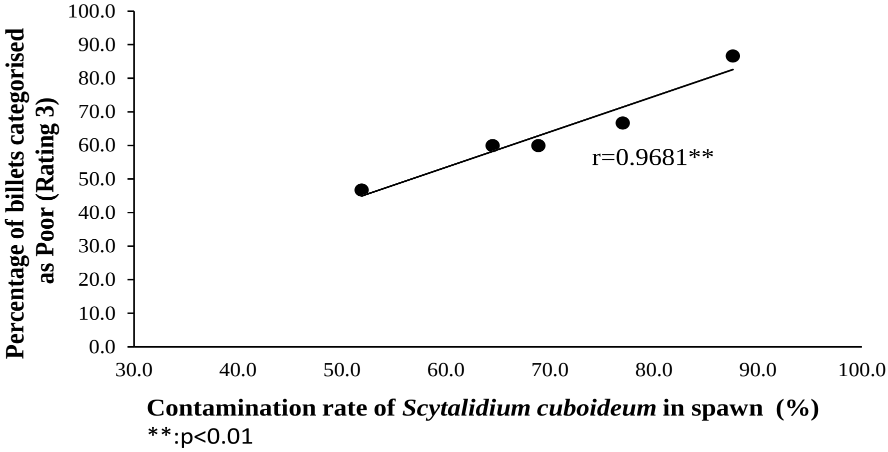

Figure 9. Relationship between the percentage of spawn contaminated with *S.cuboideum* and percentage of billets categorized as 'Poor'

Symptoms of *S.cuboideum*contamination were observed in many spawn, even after shiitake mycelia had grown. This is most likely due to the low temperatures experienced during inoculation. Although the spawn was contaminated with *S. cuboideum*, shiitake mycelia was able to outcompete the contaminant in low temperatures. Once the temperature began to rise, shiitake growth was inhibited as the temperature reached the optimum temperature for the contaminant. These symptoms of shiitake mycelia initially running, and being inhibited during warming temperatures have frequently been observed throughout Bhutan during the 2017-2018 production years (Norbu, 2019).

Further studies on the source of contamination of spawn, as well as environmental management of this contaminant should be considered to prevent further outbreaks.

5. Conclusion

The serious damage occurred in the wood log cultivation of Shiitake in 2018 and the cause and degrees of the damage were revealed through the case study conducted in Wangdiphodrang. Conclusions obtained are as follows:

- Billets with poor mycelial colonization of shiitake existed at a rate of 64.0±14.6 %.
- Low quality spawn existed at a rate of 43.0±6.3 %.
- Poor mycelial colonization in the billets was caused by infection of *S. cuboideum* in the spawn.

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Determination of Starch Content in Green Maize Cobs and its Product Development

Kinley Wangmo[f], Dechen Tshering[g], Sonam Lhamo[g], Thinley Wangdi[h]

ABSTRACT

Maize is an important crop cultivated throughout the country. Although it is nutritious containing nutrients like carbohydrates, fat, protein, some vitamins and minerals, it is often considered as poor people's food. Maize in Bhutan is generally used for human consumption in the form of grits (kharang), roasted flattened form (tengma) and quite often as cattle feed. In light of the limited option for use of maize as food and the stigma attached to its consumption, there is a need for maize product diversification into more attractive and acceptable food forms.

One potential use of maize could be starch extraction and utilization of the extracted starch in baked products. This study was conducted to determine the possibility of extracting and recovering starch, and in developing products from extracted starch. Results from this study indicate that the starch yield ranges from 208.6 g in milk stage, 316.9 g in dough stage, 507.6 g in dent stage and 540 g in physiological maturity stage from fresh 3 kg of maize grain weight. A significant difference in the percentage of starch recovered at different stages of maize grain development was observed. The starch recovered increased with the maturity of the maize grain and varied from 6.9 % at milk stage to 10 % at dough stage, 16 % at dent stage, and 17.9 % at physiological maturity stage. Four different products - cookies, fried cookies, cracker and pancake were developed from the extracted starch. Sensory evaluation results for the four products showed that overall acceptability percentage for cracker, pancake, cookies and fried cookies were 100 %, 90 %, 84 % and 28 % respectively. Based on average scores from the sensory evaluation, cracker was the most liked product and fried cookies the least. The results from the study could be beneficial in maize product development and diversification.

Key words: *Reproductive stages, starch recovery, products, sensory evaluations*

1. Introduction

Maize (*Zea mays* L.) or corn is one the popular staple foods grown across the globe. In Bhutan, maize is cultivated throughout the country, and most commonly in the eastern region of the country. It is one of the main cereal crops that is cultivated for consumption and as feed for domestic animals. In 2016, Bhutan produced 82,035 MT of maize from 56,609 acres (DoA,

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2016). The crop is cultivated by over 70% of the households and plays a critical role in household food security (NBC, 2008). According to the maize value chain report by UNDP (2016) maize is consumed as substitute of rice by milling kernels into small grits as *kharang*. *Tengma* (beaten corn) is also processed from maize kernels by roasting over a pan and flattened by a crushing machine. To a lesser extent it is also used as ingredient for brewing *Ara* (local brew) while the residues and low grade maize kernels are used as cattle feed. At a global level 64% of maize is used as feed, 16% as food for humans, 19% in industrial starch and beverage, and 1% as seed (Malhotra, 2017).

Maize, besides being used for direct consumption as human food is also a source of starch in industries and confectionaries. Starch is major form of stored carbohydrate in the plants that contains chlorophyll. Starch is produced during photosynthesis. Starch and oil in corn kernel provides energy for the seeds to germinate (CRA, 2006).

Maize kernels consist of seed coat (pericarp), starchy endosperm and the embryo (germ). The endosperm attributes to 80% of the total weight of the kernel. The matured kernel is composed of 70-75% starch, 8-10% protein and 4-5% oil (Öner, 2015). Starch is a carbohydrate reserve found abundantly in plant parts like leaves, flower, fruits, seeds, stems and roots. It's a carbohydrate polymer consisting of linked long chain glucose units from end to end. They are formed in the chloroplasts of green leaves. Amyloplasts and organelles are responsible for the starch reserve synthesis in cereals and tubers (Alcazar-Alay & Meireles, 2015).

Starch is composed primarily of amylose and amylopectin. In the normal maize starch the amylose content varies from 20 to 25% and 75 to 80% amylopectin (Popescu, Alexandru, Bărăscu, & Iordan, 2010). Isolated starch is a dry, soft, white powder which is insoluble in cold water, alcohol, ether and in most organic solvents (CRA, 2006). Maize starch forms a transparent paste and used in gelatinization of food products, powder for kids, bio- plastics which are known to be an indispensable part of packaging industries, as anti-stick agents in medical and pharmaceutical industries and as anti-caking agent in the powdered sugar. It is a valuable ingredient in food processing industries and is used as thicker, gelling, bulking and water retention agent (Sandhu & Singh, 2006).

Although it is a staple food in the eastern region it is often felt as poor cuisine compared to rice (Wangchuk & Katwal, 2014). Many prefer having rice then *kharang* (grits) in their daily diet. Even in the rural households *kharang* on its own is rarely consumed. In fact *kharang* (grits) and *tengma* (pounded corn) are the only maize products that are consumed (Wangchuk & Katwal, 2014). In light of this limited options for use of maize as food and low preference there is need to diversify maize products into more acceptable and palatable forms. Since maize contains high amount of starch a potential use could be starch extraction from maize and utilization in different products in bakeries.

With immense scope to add value and diversify the use of maize, this study was conducted with two key objectives.

- To extract starch from maize kernel at four different reproductive stages manually to develop new products and diversify its uses.
- To use the extracted maize starch to develop different maize products and evaluate the quality of these products through sensory evaluation test.

2. Materials and Method

The study was conducted at the Integrated Food Processing Plant, Lingmethang under Mongar Dzongkhag for two seasons in 2017 and 2018. The starch extraction was done at four different reproductive growth stages of maize corresponding to milk stage (18-22 days after silking), dough stage (24-28 days after silking), dent stage (35-42 days after silking) and physiological maturity at 55-65 days after silking as described in Nielsen (2018). This experiment had four treatments which included starch extraction at milk stage, dough stage, dent stage and at physiological maturity. Each treatment was replicated four times and for each replicate 3kg of maize kernel was used for starch extraction. The maize variety used in this trial was local variety Barpa.

The maize variety Barpa was harvested from farmer's field in Wengkhar separately at four different reproductive growth stages as described above. The cobs were de-husked, shelled and cleaned to obtain 3kgs of maize kernels. The grains were weighted using an electronic weighing balance. The maize grains were then grinded using the heavy duty mixture grinder (Lord Master Hammer 1600) for about 2-3 minutes and 2000ml of water was added to the grinded maize to obtain a suspension of fine particle of starch in water. The mixture was then filtered using double layer white muslin cloth. The juice was left to settle for 2-3 hours. After 2-3 hours, the juice was drained and the sediment (starch) was taken out from the container. The starch was spread on solid sheet in electric dryer (Ezi dryer) and dried at a temperature of 55^0C overnight. Dried starch powder was weighed and the data were recorded accordingly.

Four different products namely cookies, fried cookies, cracker and pancake were prepared from the starch. A sensory analysis was conducted with 50-member panelist comprising food technologist, agriculture researchers, agricultural extension officers and youth entrepreneurs. The panelist evaluated the product based on the colour, taste, texture, appearance and overall acceptability of the product using the 9-point hedonic scale (Table 1). 9-point hedonic scale is widely used method to evaluate the food products developed by Jones, Peryam, and Thurstone (1955).

Table 1. 9. Point hedonic scale

Hedonic rating	Score
Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Source: Jones et al. (1955)

The panelists were presented four different products prepared from the maize starch. Testing were performed one after another and their rating were recorded in a 9-point hedonic scale sheet provided to the panelist.

The data from the test were analyzed using Statistical Package for Social Science (SPSS) version 22.0. Quantitative data such as weight were analyzed using One Way ANOVA and Microsoft Excel 2008. P values ≤ 0.05 were considered significant in all the analyses. The results of qualitative data on sensory evaluation were interpreted in percentages.

3. Results and Discussion

3.1 Starch yield from different stages of maize

The result shows that there was significant increase of starch yield with maturity of the maize. There was a significant difference ($P < 0.0001$) among the four different stages of maize. The starch yield ranges from 208.6 g in milk stage, to 316.9 g in dough stage, 507.6 g in dent stage and 540 g in physiological maturity stage from 3 kg of fresh grain weight (Table 2). The maximum starch yield was recorded at physiological maturity stage and minimum in milk stage. As the corn matures the starch content gradually increases from milk stage at 18-22 days after silking, dough stage at 24-28 days after silking, dent stage at 35-42 days after silking and physiological maturity stage at 55-65 days after silking (Nielsen, 2018).

Table 2. Maize starch yield at different stages of maize

Variety	Stages	Mean starch content from 3 kg fresh kernel (g)
Barpa	Milk stage	208.6d
	Dough stage	316.9c
	Dent stage	507.6b
	Physiological maturity stage	540.0a
P-value		*<0.0001*
CV (%)		*0.69*

Means with the same letters in the column are not significantly different at 0.05 probability level using Duncan Multiple Range test

The study also revealed that there was significant difference ($P < 0.0001$) in starch recovery rate for different stage of maize (Figure 1). The recovery rate of starch increased with the maturity of maize kernel. The highest recovery rate of starch was obtained from physiological maturity and lowest recovery rate from milk stages. Similar results were reported by Nleye, Chungu, and Kleinjan (2019) supporting that at kernel milk stage (approximately 18-22 days after silking) starch accumulation occurs rapidly and continues to increase as the kernel develops and reaches physiological maturity stage at 55 to 65 days after silking when black layers develop at the base of kernel. This indicates that the starch content will be minimal at early stages of development and gradually increases with a maximum at the matured stage.

Ketthaisong, Suriharn, Tangwongchai, and Lertrat (2013) also reported similar results in the starch content of waxy corn that showed increasing trend in relation to delay harvesting from optimum stages until physiological maturity stages where starch granular size increased in relation to kernel development. According to Burrell (2003) maize kernel contain about 66% starch and optimum starch is extracted from freshly harvested grain at physiological maturity when the starch content in the endosperm of the kernel will be higher than in other stages. Cui, Dong, Zhang, and Liu (2014) also observed that maize kernel contains about 70% by weight starch.

The starch contained in the endosperm of the kernel was also affected by external factors like altitude and pests. The recovery rate of maize starch extraction also depends on handling and efficient starch extraction process.

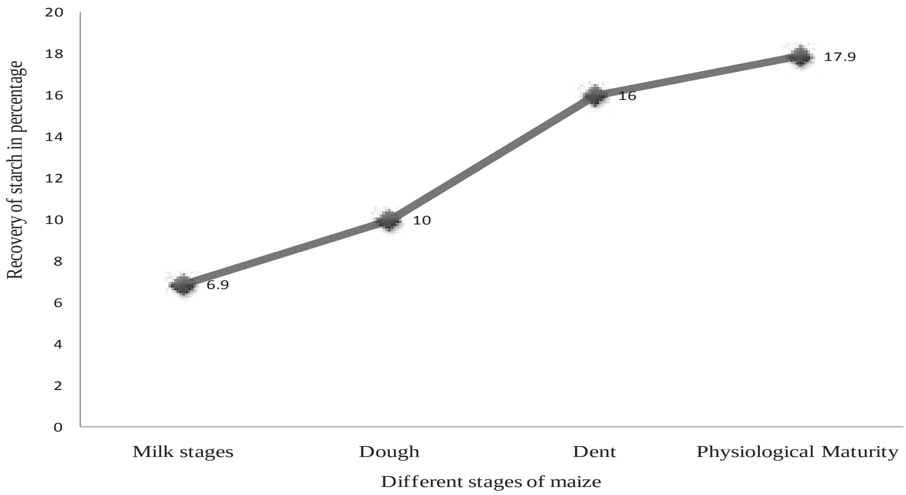

Figure 10. Starch yield in percentage

3.2 Sensory evaluation of the products

Four different products such as cookies, fried cookies, cracker and pancake were developed from the starch powder extracted from maize kernel. The products were evaluated based on colour, flavour, taste, texture, appearance and overall acceptability by the panelist. The results from the sensory evaluation are discussed in two parts. First on the overall acceptability of the product based on the percentage of panelist who as described in the hedonic scale 'liked' or 'disliked' the product, and second on specific parameters based on the average representative score of the products for the evaluated parameters given by 50 panelists.

3.3 Overall acceptability of products

The results from the overall acceptability of products were expressed as percentage of panelist who have rated the overall acceptability as per the hedonic scale as given in Table 3. A cumulative of the percentage of panelist who have rated the product in the 'like scale' and 'dislike scale' are taken to indicate how many panelists liked or disliked the product. 100% of the panelist liked the cracker while 90% of panelist liked the pancake with remaining panelist being neutral. 84% of the panelist liked the cookies, 4% remained neutral and 12% disliked the cookies. It was found that for overall acceptability, the fried cookies was the least liked product with only 28% panelist preferring the product, 50% disliking it and 22% panelist being neutral. Majority of the panelist thus, preferred the cracker followed by pancake and cookies.

Table 3. Percentage of Panelist according to their preference for overall acceptability of maize starch products

9-Point Hedonic scale	Percentage score for different products (n=50) Cookies	Fried cookies	Cracker	Pancake
Dislike extremely	0	0	0	0
Dislike very much	0	0	0	0
Dislike moderately	0	14	0	0
Dislike slightly	12	36	0	0
Neither like nor dislike	4	22	0	10
Like slightly	18	28	4	26
Like moderately	32	0	20	14
Like very much	26	0	48	50
Like extremely	8	0	28	0
Mean score on 9-point hedonic scale	6.80	4.64	8	7.04
Most preferred product (ranking)	3	4	1	2

3.4 Sensory evaluation scores

Average score of the parameters in the sensory evaluation was calculated from the scores given by 50 panelists and plotted out as given in Figure 2. Higher the score (from 9-6), the more preferred is the particular parameter, lower the score (4-1), the less preferred is the parameter and 5 being neither like nor dislike score as per the hedonic scale.

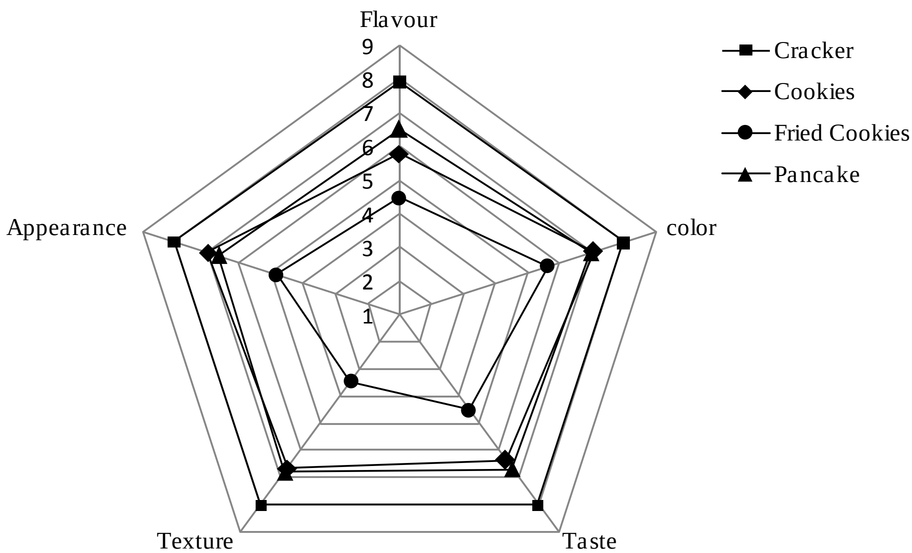

Figure 2. Average sensory score of maize starch products

3.5 Colour of the products

Colour is an important quality attribute in food that influences consumers' choice and preferences. The colour of the food surface is the first quality parameters that consumers consider and are critical to product acceptance (Pathare, Opara, & Al-Said, 2013). As per the average score in Figure 2, the colour of cracker was highly liked, while colours of both the pancake and cookies were liked moderately, followed by fried cookies that was liked slightly.

3.6 Flavour of products

Flavour of a product is described by its aroma and taste, and has impact on the acceptability of the product as well as in promoting interest for its heightened consumption (Barrett, Beaulieu, & Shewfelt, 2010). As per the average scores (Figure 2), the flavor of cracker was liked very much, pancake and cookies was liked moderately and fried cookies were disliked slightly.

3.7 Taste of products

The results of average score for taste showed that the cracker and pancake was liked extremely, cookies liked slightly and the taste of fried cookies was neither liked nor disliked (Figure 2).

3.8 Texture of products

Texture of the food products are important parameters for the quality products leading to consumer acceptance (Rouf Shah, Prasad, & Kumar, 2016). The texture of the cracker was liked very much, liked moderately for pancake and cookies, and disliked moderately for fried cookies.

3.9 Appearance of the products

Appearance of a product consists of the products size, shape, uniformity, surface gloss or dullness, and the nature and degree of pigmentation (MacDougall, 2003). The appearance of the cracker was liked very much, pancake and cookies were liked moderately, and fried cookies were neither liked nor disliked (Figure 2).

4. Conclusion

Maize is an important cereal crop for food, feed, seed, beverages and starch purpose. The major composition of maize kernel constitutes mostly starch and few quantities of protein, oil and minerals. Starch content in the grains varies with growth stages of the crop. There is gradual increase in starch content and its recovery rate from milk stage till physiological maturity. Maximum starch content is found in physiological maturity stage amongst the four growth stages.

Utilization of starch for different product development is one option to make best use of maize crop other than *Tengma* (roasted and flattened) and *Kharang* (grits). Of the four products developed from maize starch, the most preferred was cracker followed by pancake and cookies while the least preferred was fried cookies. All the organoleptic parameters of cracker had scores corresponding to ‘liked very much’ on the hedonic scale, thereby, justifying why it was preferred the most. Further, improvement on sensory parameters such as flavor, taste and texture of pancake and cookies could increase the overall acceptability of the products.

Maize starch extraction and product development from the starch could be one of the potential enterprises that interested entrepreneurs and community groups could focus on, and that could ultimately encourage our farming communities to go for large scale maize production.

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Evaluation of High Density Polyethylene as Alternatives for Wooden Poles in Electric Eence

Tshering Penjor[i], Lhap Dorji[i], Geley Namgay[i], Pema Thinley[i], Choki Nima[i]

ABSTRACT

To reduce wooden pole usage in electric fencing, ARDC-Wengkhar with financial support from the Bhutan Trust Fund for Environment Conservation (BTFEC) has been evaluating High Density Polyethylene (HDPE) pipe as an alternative for wooden poles in electric fence. The trial was conducted in two remote villages in Saling gewog under Mongar dzongkhag. The HDPE with two different specifications of 75mm and 50mm were evaluated. The initial investment cost of HDPE pipe is found to be more than three time higher than that of wooden poles which could not be afforded by average Bhutanese farmers. However, HDPE pole substitution could save about 41.63 m3 of forest volume which could produce Nu. 42,448 worth of ecological services for the country in construction of 1km electric fence.

Keywords: *Crop Damage, HDPE pipe, Electric fence, Ecological Services*

1. Introduction

Crop damages by wild animals continue to be one of the major challenges faced by the farming communities in Bhutan. In the effort to mitigate crop damage, ARDC Wengkharin collaboration with NPPC, Simtokha developed a low cost fabricated electric fence which is currently being promoted nationwide. This has made immense contribution towards resolving human-wildlife conflicts and helped farmers protect almost 80-100% crop loss since 2009. Between 2009 and 2018, a total of 3492 km of electric fences have been established protecting 39, 346 acres of agricultural land across the country (MoAF, 2018).

Although the electric fence has helped ease the crop damage problems, but the need for huge number of wooden poles extracted from government reserved forests is a huge concern expressed by different stakeholders, particularly, the Department of Forests and Park Services. It is estimated that about 450 wooden poles are required to construct 1 km of electric fence (Penjor et al., 2013). Consequently large volume of wood has been extracted from the government reserved forests for construction of electric fences between 2009 and 2018. Additionally, many of these sites could have used more additional wooden poles as replacement due to their short

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life span. Generally most of the wooden poles used for electric fence in Bhutan need to be replaced within 3-5 years after initial installation although there are hardy species with extended life spans of beyond ten years.. Therefore to reduce wooden pole usage in electric fencing, ARDC-Wengkhar with financial support from the Bhutan Trust Fund for Environment Conservation (BTF-EC) has evaluated High Density Polyethylene (HDPE) pipe as an alternative for wooden poles in electric fence. The HDPE pipe has a minimum service life span of 50 years and if it is corrugated it can exceed 100 years (Lester, 1998). The study was conducted in two sites in Mongar dzongkhag with following objectives:

- To compare the initial investment cost of High Density Polyethylene (HDPE) poles with standard wooden poles in establishment of electric fence
- Conduct simple Cost Benefit Analysis of High Density Polyethylene (HDPE) poles within its minimum service life span
- To estimate the value of ecological services provided by the standing trees which are substituted by HDPE pipes

2. Materials and Methods

2.1. HDPE pole specification and manufacturing

The Bhutan Polythene Company Ltd., in Phuntsholing manufactures various types of HDPE pipelines, mainly for drinking water supplies and irrigation purposes. They also manufacture HDPE pipes with customized size and specification based on customer demand. For our study we ordered the following sizes and specification suited for electric fence poles.

- Pipe type= HDPE non-corrugated type
- Pipe outer diameter= 75 mm/50mm
- Pipe length= 2 meter
- Maximum pressure rating =PN 12.5 (187.5 psi)

2.2. Site selection and trial setup

Two villages under Saling geogs, Mongar Dzongkhag were selected to install the electric fence using HDPE poles (Table 1). Another village under Tsamang geog of Mongar Dzongkhag was selected to install electric fence using normal wooden poles (Table 2). Those selected villages are located in remote area and were constantly being raided by wild animals such as wild pig, monkey, porcupines and Samber deer. All the installation procedures and equipment standards were referred from the Technical Reference Manual for Installation and Maintenance of Electric Fence, 2014.

Table 1. Site information on electric fence setup using HDPE poles

Electric fence parameters	Ligar, Thridangbi (50mm HDPE)	Galingkhar (75mm HDPE)
Length of electric fence	430 m	350 m
No. of beneficiary households	3	1
No of HDPE pole used	120 nos	140 nos
Amount of GI wire used	60 kg	50 kg
No of Energizer	1nos	1 nos
Energizer powered by	12V battery, 30 watt solar panel	12V battery, 30 watt solar panel

Table 2. Site information on electric fence setups using wooden poles

Electric fence parameters	Thenbang village under Tsamang Geog, Mongar
Length of electric fence:	1500 m
No. of beneficiary households	5
No of Wooden pole used	675nos
Amount of GI wire used	75 kg
Amount HDPE insulator used	495 m
Amount of 3 inch nail used	63 kg
No of Energizer used	1nos
Energizer powered by	12V battery, 30 watt solar panel

2.3. Cost benefit analysis of high density polyethylene (HDPE) poles

Simple Cost Benefit Analysis (CBA) of HDPE poles were carried out based on Net Present Value (NPV), Benefit Cost Ratio (BCR) and Payback Period (PP) of all the monetary values over the minimum life span period of the HDPE pipe which is taken at 50 years. The discount rate for Net Present Value (NPV) of the cost and benefit were calculated from current interest rate on fixed deposit of the Bank of Bhutan Ltd. which is at 7.25% per annum. The actual length of electric fence installed and amount of material used varied with village but for the study purpose, calculations were made on per kilometer basis. While performing analysis, we assumed the average service life of wooden-poles at 5 years and HDPE pipes at 50 years. The initial costs on purchase of energizer, solar panel, GI wire, batteries, and charge controller are assumed to be same for either type of EF.

2.4. Estimating the value of ecological services provided by the standing trees substituted by HDPE pipes

A study conducted by Kubiszewski et al. (2013) estimated the value of ecological services provided by different forest cover and land use types in Bhutan using benefit transfer methodology. The total value for the ecosystem services in Bhutan was estimated USD 15.5 billion/year (Nu. 760 billion/year) which was significantly greater than the Gross Domestic Product (GDP=USD 3.5 billion/year). Benefit transfer is the process of utilizing existing valuation studies or data to estimate the value of ecosystem services in one location and transfer them to ecosystem services in a similar location (Costanza & Folke, 1997). The transfer method involves obtaining an economic estimate for the value of market and non-market services through the analysis of a single study, or group of studies, that have been previously carried out to value similar services. In the current study, we estimated the value of ecosystem services provided by the volume of forest which were substituted by HDPE pipes by using the baseline data provided by Kubiszewski et al. (2013). The volume of the forest in a hectare is adapted from the findings of DoFPS (2016). The Huber formula ($V=\pi r^2 h$) stated by de Leon & Uranga (2013) has been applied to measure the total volume of forest harvested to construct 1km fence. The total volume of forest harvested to construct 1km fence is computed based on the timber extraction and distribution modalities applied by the Department of Forest and Park Services as 40% timber and 60% firewood on standing volume (DoFPS, 2017).

3. Results and Discussion

3.1. Initial investment cost for establishment

Initial investment (material and installation) cost for HDPE and wooden poles based EF are compared and presented in Figure 1. The figure shows that total investment cost of 75mm HDPE pole is Nu.3, 26,752 which is more than five times higher than the total investment cost of using wooden poles (Nu. 76207) for establishment of 1km electric fence. On other hand, the total investment cost for EF using 50mm HDPE poles is Nu. 1, 72852 which is three times higher than wooden pole based EF. The cost difference is mainly due to the higher cost involved in purchase of HDPE poles from Bhutan Polyethylene Company compared to the minimal cost involved in acquiring wooden poles from nearby forests.

The other cost difference is from the use of 25 mm HDPE pipe and insulator preparation along with that of 3-inch nails in wooden pole based EF. In HDPE pole the fence GI wires are directly passed through the 8 mm diameter holes drilled in the HDPE pole and the additional insulators and 3-inch nails are not required.

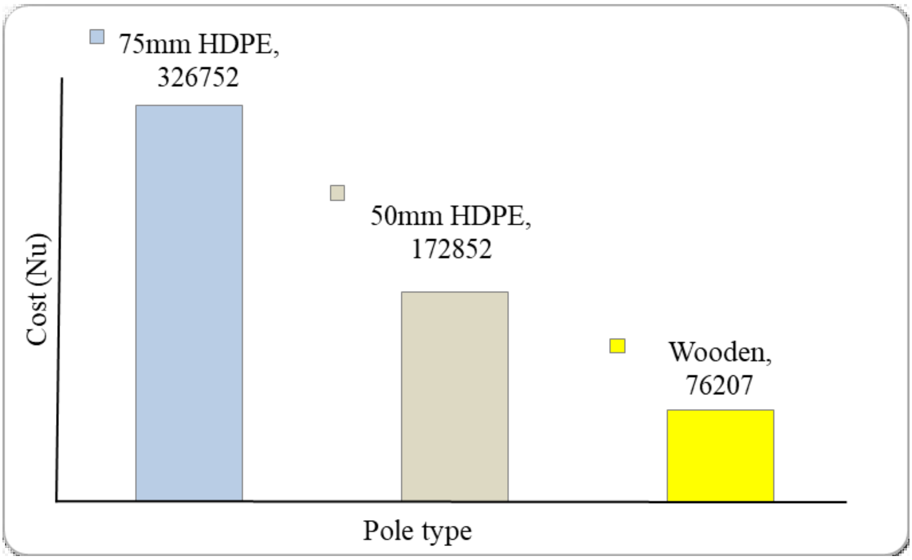

Figure 1. Initial investment cost of three different pole based EF

3.2. Cost Benefit Analysis of HDPE pipe as electric fence pole

Simple Cost Benefit Analysis of HDPE poles were carried out based on Net Present Value (NPV), Benefit Cost Ratio and Payback Period of all the monetary values over the minimum life span period of the HDPE pipe and presented. The cost benefit analysis model of 75mm HDPE and 50mm HDPE is shown in the Table 5 and Table 6 respectively. The only difference is the recurrent cost of Nu. 29, 280 entailed for the replacement of wooden poles considering its service life of 5 years. This amount on other hand is assumed as saving or benefit of using HDPE pipe as electric fence pole. This cost includes the cost of wooden poles, transportation and labor charge for reinstallation of electric fence. The CBA model shows that NPV of using 75mm HDPE as EF pole stands at Nu. – 2, 58,985 with the BCR of 0.21 (Table 5).

Table 5. Cost Benefit Analysis of HDPE (75mm) and wooden poles over the period of 50 years for 1km electric fence.

Year	HDPE initial cost	Wooden Pole cost	Benefit of using HDPE	Present Value of benefit (HDPE pipe) at discount rate of 7.25%
0	326752	76207	0	0
5	0	29280	29280	20634
10	0	29280	29280	14541
15	0	29280	29280	10247
20	0	29280	29280	7221
25	0	29280	29280	5089
30	0	29280	29280	3586
35	0	29280	29280	2527
40	0	29280	29280	1781
45	0	29280	29280	1255
50	0	29280	29280	885
Total	326752	369007	292800	67767
			NPV	-258985
			BCR	0.21

The NPV still stands at the negative value of Nu. – 1, 05,085 while running CBA model for 50mm HDPE based EF (Table 6). The BCR of using 50mm HDPE is at 0.39. The result clearly suggests that electric fence establishment using HDPE pipe either of 75mm nor the 50mm specification is not financially feasible at the present interest/discount rates.

Table 6.Cost Benefit Analysis of HDPE (50mm) and wooden poles over the period of 50 years for 1km electric fence.

Year	HDPE initial cost	Wooden Pole cost	Benefit of using HDPE	PV benefit HDPE
0	172852	76207	0	0
5	0	29280	29280	20634
10	0	29280	29280	14541
15	0	29280	29280	10247
20	0	29280	29280	7221
25	0	29280	29280	5089
30	0	29280	29280	3586
35	0	29280	29280	2527
40	0	29280	29280	1781
45	0	29280	29280	1255
50	0	29280	29280	885
Total	172852	369007	292800	67767
			NPV	-105085
			BCR	0.39

The small discounted benefit accumulated at the end of HDPE service life of 50 years is worked to figure out the period where by the cumulative cost equals to cumulative return of the technology (figure 2). The cumulative return of using HDPE at the end of its service life accounts to Nu. 67, 767 which is far less than the initial establishment cost of Nu. 1, 72,852.

Figure 2. Payback time of HDPE pipe (50mm) within its service period of 50 years

3.3. Estimating the value of Ecological Services provided by the standing trees substituted by HDPE pipes

Forest ecosystem provides different types of services which are generally divided into economic value, ecological value and social value. The ecological value mainly includes the water conservation, soil conservation and fertility, soil improvement, carbon sequestration and oxygen release, environment purification, forest protection, biodiversity maintenance and so on (Krieger, 2001). The value of ecological services in Bhutan was first estimated by Kubiszewski et al. (2013) at a mean value of US $ 5040 per hectare/year by the temperate forests. This value was used in our study to estimate the value of ecological services that may be produced by the number of standing trees which are substituted by HDPE pipes, and otherwise would be cut down and used in electric fence.

In Bhutan, the volume of forest is estimated at 346 m^3 per hectare (DoFPS, 2016). A total volume of 41.63 m^3 of forest is harvested in constructing 1 km fence. Therefore, our analysis assumed that every 1 km length of electric fence would save 41.63 m^3 of forest having wooden fence pole replaced by HDPE. As presented in Table 7, total value of ecological benefit of US $ 606.40 is banked in very first year while using HDPE as alternative to wooden poles in construction of a 1 km fence. Through the entire service life of HDPE, the ecological value reaches to Nu. 4, 66,928 computed against wooden poles being replaced at every 5 years interval. Based on this assumption, a total forest volume of 457.93 m^3 will be saved at the end of 50 years by constructing and maintenance a 1 km HDPE fence.

Table 7. Value of Ecological Services provided by the standing trees

Year	Vol. of forest harvested to construct 1km fence (m3)	Total vol. per hectare by forest (m3)	Ecological service value per year/hectare ($)	Total value of ecological service ($)
1	41.63	346	5040	606.4
50	457.93	346	5040	6670.4
	Total value in Nu.			466928

4. Current attribute of Electric Fencing to forest ecological service

A total length of 3492 km of electric fencing (EF) was constructed within the span of 9 years (2009-2018) in our country accounting to 15,71,400 numbers of wooden poles. This translate to 1, 45,371.96 m^3 of forest harvest exclusively for construction of EF. Subsequently 420 hectares of forest has been already harvested within these 9 years in addressing human wildlife conflict. By now, Bhutan has lost the ecological value worth of Nu. 2.1 million, which otherwise should have contributed by that volume of forest used in constructing EF. The officials with Department of Forest & Park Services stated that on an average there is a demand of 10,000-12, 000 numbers of fencing posts from one chiwog annually. If applied to gewog, dzongkhags and the country as a whole, it translates to huge destruction to forest within short period. Further, this will affect the growth of non-wood forest products as well as eventually lead to wild animals interfering with the human settlements.

5. Conclusion

Electric fence has hugely helped Bhutanese farmers in protecting their crops from wild animals' damage. However, the need for huge number of wooden poles to install electric fence from government reserved forests is a major concern in terms of sustainability. ADRC- Wengkhar conducted the study on the use of High Density Polyethylene (HDPE) pipe as an alternative to wooden poles in electric fence in 3 villages in the eastern Bhutan. The initial investment cost of HDPE pipe is found to be than three time higher than that of wooden poles which in no way could be paid back from the accumulated benefits within the service life of the HDPE pipes. We also estimated the monetary value of the ecological services of the forest which are substituted by HDPE pipes. The ecological service provided by these forests within the service period of the HDPE pipes is estimated to be worth at Nu. 0.47 million in construction of 1km EF. This benefit will motivate those in the government or decision-makers to opt for HDPE-based electric fence system. The initial investment cost should be subsidized or borne by the government or else most Bhutanese farmers will not be in a position to reap the benefit HDPE-based electric fence.

Acknowledgement

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Analysis of Government Supported Farm Machinery Custom Hiring Services in Bhutan

Kinga Norbu[j] and Chetem Wangchen[j]

ABSTRACT

Custom hiring services have been institutionalized with the creation of the Farm Machinery Corporation Limited. It is being implemented nation-wide to accelerate mechanized farming. The charges levied on the farmers are highly subsidized. This study was undertaken to assess the hiring costs, commercial viability of the operation and rationalize the rates and subsidy components. The cost of operation of farm machinery under government programme is divided into two sub costs (I) Fixed Cost and (II) Variable Cost, and government endorsed parameters were used for the custom rates calculation for different machine through regression analysis. An analysis of breakeven point on present endorsed hiring rate was done to ascertain the economic trend of this activity. Government subsidy on each machine operation is also shown. The analyses provide a positive outlook for the machine owners and corporations to take up the hiring scheme based on nationally endorsed parameters. The custom hiring analysis also gives a good guide on the custom hiring rates to be charged based on the operating days.There is more profit especially on tractors and mini combine harvesters compared to other machines. This is a favourable business opportunity. However, there is also an opportunity to reduce the custom rates to bring down the overall cost of farming using machine and reduce burden on government subsidy. It will also encourage private sector participation in the programme.

Keywords: *Farm machinery, Custom hiring rate, Break-even point, Subsidy*

1. Introduction

Agriculture is the primary sector in Bhutan with 58% of the population depending on it for their livelihood (MoLHR, 2016). To a large extent, farming is performed manually and through animal draft power. Higher forms of mechanization are limited due to rugged terrain. Due to increasing farm labour constraints, major efforts are being initiated by the government to promote farm mechanization activities in the country. One prominent intervention has been the supply of labour-saving agricultural machines mainly to individual farmers at subsidized prices including after-sales services. Although the supply of the machines brought tremendous benefits to the farming communities, the financial burden on the government increased substantially. Besides, the system of individual ownership did not result in optimum use of the machines.

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Machines therefore, remained extremely underutilized while the demand kept increasing rapidly. There is also the low-income groups of farmers who combined with low land holdings, can neither afford nor economically justify the investment in machines individually. On the other hand, the encouragement of private community group ownerships has not resulted in adequate rate of adoption (AMC, 2019).

In order to provide services to as many farmers as possible while simultaneously enhancing efficient utilization, farm machinery hiring services were initiated. Although the initiative had been taken up by the Agriculture Machinery Centre (AMC) many years ago, major up-scaling of the activities started from 2016 with the establishment of the Farm Machinery Corporation Limited (FMCL). It is also anticipated that the private sector hiring services will pick up gradually, thereby reducing the need for continued state support. The corporate hiring services currently being at the promotional stage, the rates applied constitute substantial subsidies, which the government provides to the corporation.

There is huge demand for farm machinery such as power tillers and tractors for primary and secondary tillage operations. Considerable demands still exist with preference for individual ownership although the land holdings do not justify it and that most do not provide hire services. This trend needs to be discouraged through awareness on the economic cost analysis and hiring system. Chahal and Malhi (2005) studied the societies of Ludhiana and Moga and found that the annual use of implements like disc-harrow, seed drill and bund former in the societies was 10 times more than that of farmers owned. The machine owners need to be educated that hiring out their machines is a profitable business and is also more economical than owning them if their individual land holdings are small. Chaudhary (2006) reports that average total running cost of tractor by individual ownership was Rupees 574.69 per hour whereas the cooperative societies cost was 39% lower than the total cost per hour of tractor. Verma (1985) conducted a study on farm size and economic efficiency in Punjab. The study showed that large farms gained much more in terms of economic efficiency as compared to the medium and small farms which gained only 43.04% and 17.02%. This was because large-scale farmers had better machinery while small farmers could not afford it. So there is good scope for custom hiring of machinery for small farmers. There is a stipulated time available for each operation in each season which makes it all the more imperative to calculate machine requirements and economically study the cost of operation.

Presently, hiring in Bhutan is not at the commercial scale and the informal hiring practiced is purely based on the convenience of the machine owners, and hiring rates are informal without any basis. Hence, it has become important to come up with a study on the hiring rates to be recommended to the farmers.

This study is to review the present government hiring rates using the break-even analysis and assess the true margin, and come up with recommendations for the future on the required government subsidies.

2. Material and Methods

The costs of operations of farm machinery are divided into two sub costs (I) Fixed Cost and (II) Variable Cost, where fixed cost is independent of operational use while variable cost varies proportionately with the coverage area or the machine use. The main components of the fixed and variable costs are given below.

1) Annual Fixed Costs
   i) Depreciation cost
   ii) Interest on investment
   iii) Insurance cost
   iv) Shelter cost for the machine
   v) Registration cost
2) Annual Variable Cost
   i) Fuel cost
   ii) Lubrication cost
   iii) Labour wages
   iv) Repair and maintenance cost

2.1 Calculation of the Fixed Cost of farm machinery

i) Depreciation cost

According to Kepner et al. (2005), the annual depreciation was calculated as

$$D = \frac{(P - S)}{L}$$

Where

D: Yearly depreciation, the annual decrease in the value of the machine

P: Purchase price of the machine

S: Salvage value or the selling price of the machine after its useful life and normally adopted as 10 % of the machine price

L: Useful life of the machine

ii) Interest on investment: It is normally the interest amount that can be generated from a fixed deposit. In Bhutan, the maximum interest generated through fixed deposit is 7.5% (BoBL, 2019).

According to Kepner et al. (2005) and Khairo et al. (2009) the annual interest on the investment is calculated as follows:

$$I = \frac{(P + S)}{2} \times \frac{i}{100}$$

where, I=Interest amount, i= Annual interest rate for buying a machinery

iii) Shelter: This is the cost associated with having a shed used primarily to house the machinery. Shelter cost is calculated at 1.5% of the purchase price of the machinery

$$Sc = \frac{1.1P}{2} \times \frac{is}{100}$$

Where Sc=Shelter cost, is = Hiring cost of the shelter (1.5% per annum for the agricultural use).

iv) Insurance and taxes: It is the amount spent on insurance every year as these machines need to be insured as they are movable machines and are prone to eventualities like accidents.

$$In = \frac{1.1P}{2} \times \frac{in}{100}$$

Where, In =Insurance and taxes amount; in= Annual insurance and taxes rate (2% per annum for agricultural use).

V) Registration cost: It is calculated as Nu 1000 per year as the renewal and registration cost for farm machinery in Bhutan.

2.2 Calculation of variable cost of the farm machinery

i) Fuel Cost

For simplicity, fuel cost was calculated as:

Fuel cost (Nu h^{-1}) = fuel price (Nu L^{-1}) x Fuel consumption (L h^{-1})

ii) Lubrication oil cost

Average lubrication cost = 1.5% of fuel cost (Nu h^{-1})

iii) Repair and maintenance cost

According to Kepner et al. (2005) it is taken 2.5% of the purchase price. However, for Bhutanese terrain, 20 % is proposed as the repair needed is frequent.

RM = 20 % x Purchase price of farm machinery (Nu)

iv) Operator and labour wages

The labour cost. It is assumed as Nu 700 /day

Labour cost = Number of days x Labour charge (Nu d^{-1})

2.3 Analysis

Cost of operation is the cost involved in the operation of the machine in the field

$$CoO = \frac{TotalAnnualCost\ (\frac{Nu}{year})}{Capacityofthemachine\ (\frac{acre}{year})}$$

Where total annual cost includes both fixed cost and variable cost. The capacity of the machine refers to its capacity in a year.

v) Overhead cost: It includes the cost involved in arranging the operation from office, power, office rent, telephone calls, the machines transportation cost to the field and off the field, etc. It is adopted as 15% of the cost of operation of the machine. The value adopted is normally 10% overhead and a contingency of 5% of the operation cost per day is incorporated.

vi) Profit Margin: The profit margin is adopted at 10 % of the cost of operation, which is the difference between the cost and the rate charged.

vii) Hiring rate: It is inclusive of the cost of operation, overhead cost involved and the profit margin. This is the rate chargeable for a quantity of service based on days, hours or area covered, provided to the client receiving the service.

viii) Break-even point analysis: Break-even point (BEP) is the point at which the total hiring cost is equal to the total costs. It is also frequently calculated in terms of area coverage

ix) $$BEP = \frac{(Fixedcost)(\frac{Nu}{year})}{\left[(Hiringcost)-(Variablecost)(\frac{Nu}{(h)(acre)(year)})\right]}$$

x) The hiring charges in Nu/h and break even in hours can be calculated. This can be done

$$Customrate\left(\frac{Nu}{h}\right) = \frac{Nu/acre}{acre/h}$$

Where Nu/acre is the custom rate in acre and acre/h is the field capacity of the farm machinery. The nationally approved parameters based on the actual field results and experiences had been adopted for calculation as shown in Table 1.

Table 1. Hiring cost parameters for custom hiring analysis

Description	Power tiller	Tractor above 34hp	Tractor 34hp	Tractor 18hp	Paddy reaper	Combine harvester	Paddy Transplanter	Water pump	Mini Tiller
Initial Cost	302,839	1,300,000	1,000,000	800,000	130,000	1,300,000	150,000	252,927	257,000.00
Life of machine in years	10	10	10	10	6	10	6	10	10
Operating hours/day	8	8	8	8	8	8	8	8	8
Operating days /year	70	70	70	70	20	50	20	30	50
Operating hrs/year	560	560	560	560	160	400	160	240	400
Capacity (acre/h)	0.1	0.3	0.25	0.18	0.3	0.3	0.3	0.25	0.06
capacity of the machine per year (acre/year)	56	168	140	100.8	48	120	48	60	24

The parameters were endorsed by the Ministry of Agriculture and Forests' (MoAF) price fixation committee (AMC, 2019) based on the past years' operating costs and expenses of the hiring operation as shown below.

Table 2. Revised and approved parameters for operating cost

Description	Revised criteria	Remarks
Repair/ year	20% of the from initial cost	Spare parts and transportation are expensive
Fuel cost (Nu/L)	60	The cost of diesel fuel as of today
Lubrication cost	1.5% of fuel cost	Its a standard requirement to change
Operator charge (Nu/day)	700	Operator wages. Still the labour cost in western region is more expensive
Transportation during hiring	10% of operation cost	Should be met from hiring
Overhead cost	10% of operation cost	Previous is very high
Contingency cost	5% of the operation cost	Accidents, natural calamities affects are included
Profit Margin	10% of operation cost	Hiring should be sustainable and continued
Total variable cost % range	55%	

Based on above parameters, a regression analysis was conducted for all farm machinery and graphs plotted to come up with trends of the hiring rates based on the operation duration.

3. Results and Discussion

3.1 Custom hiring rates for different machines

The operating cost of different farm machines shown in graphs provide the hiring cost/day based on the operating days in a year. The empirical formula through regression had been generated. However, agricultural work is seasonal and during the season everyone require machines at the same time. This substantially limits the duration of the use of the machines in a year. More machines are needed at the same times due to the seasonal nature of agricultural work.

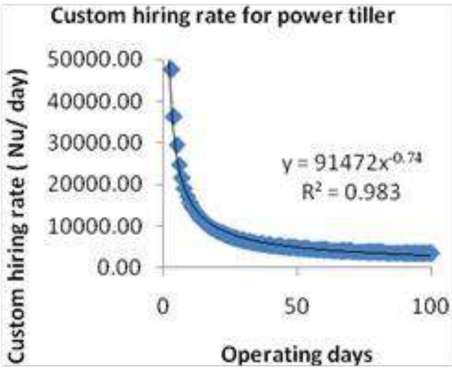

Figure 1. Custom rate for power tiller

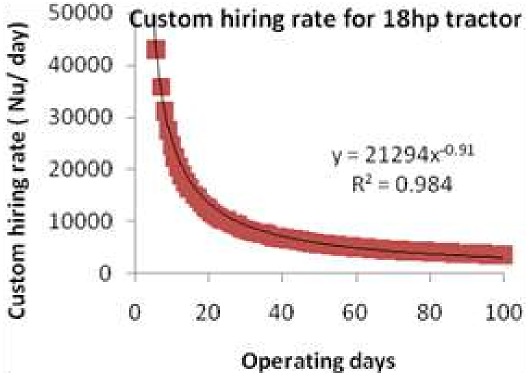

Figure 2. Custom hiring rate for 18 hp tractor

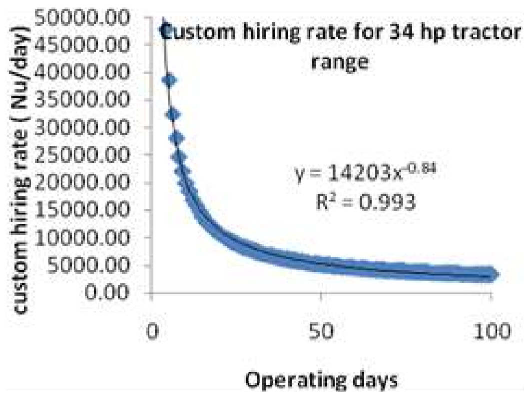

Figure 3. Custom rate for 34 hp tractor

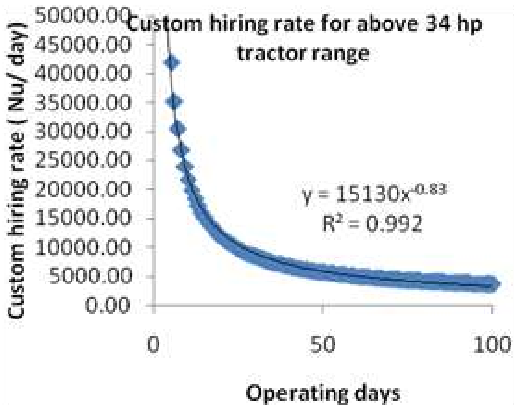

Figure 4. Custom rate for 34hp and above

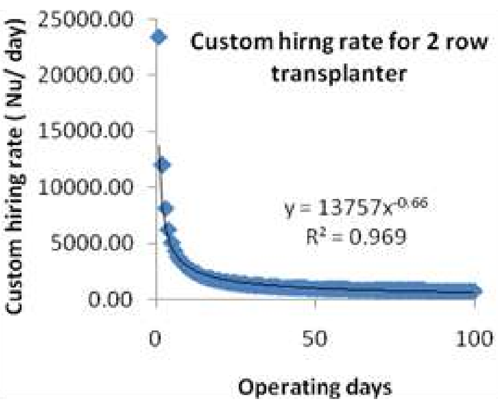

Figure 5. Custom rate for transplanter

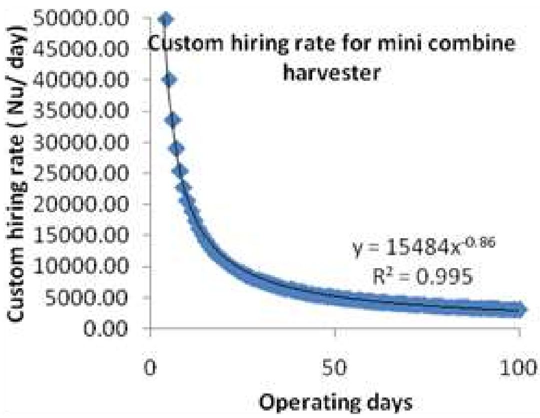

Figure 6. Custom rate for mini combine harvester

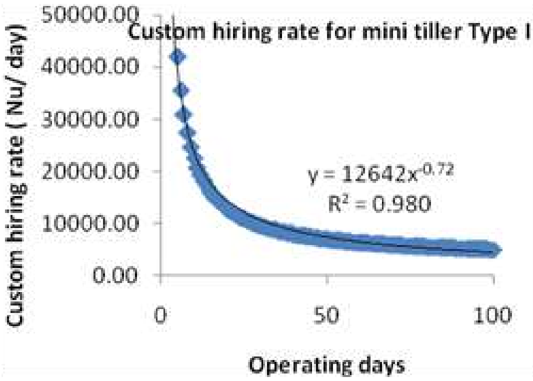

Figure 7. Custom rate for mini tiller I

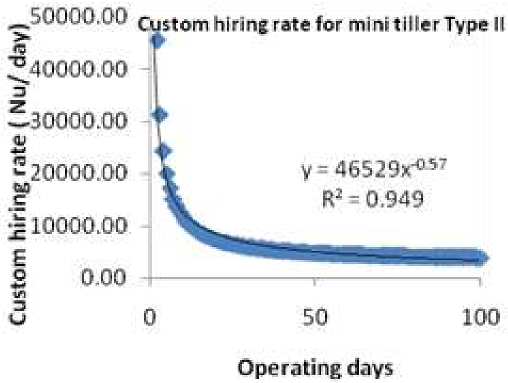

Figure 8. Custom rate for mini tiller II

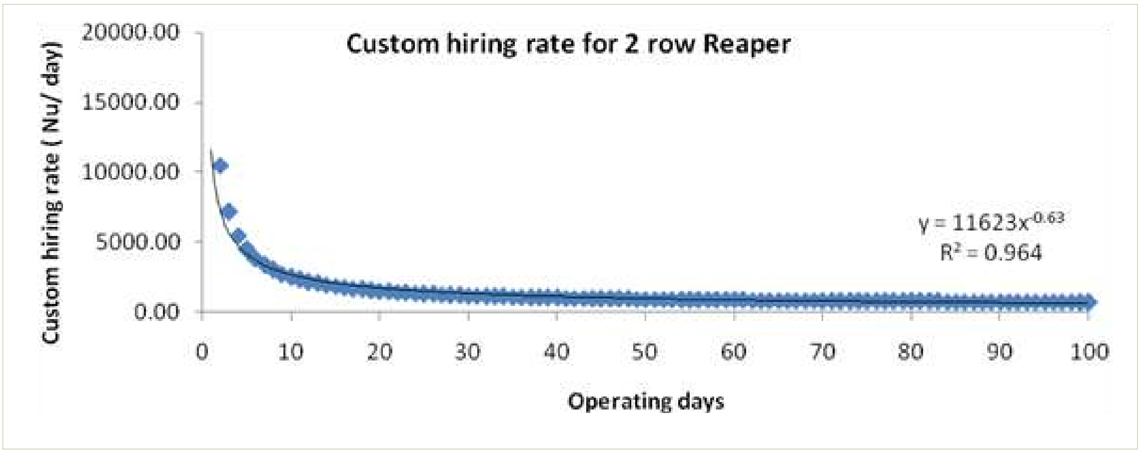

Figure 9. Custom rate for 2 row reapers

3.2. Determination of economic feasibility of farm machinery

After calculating the BEP, it is observed that most of the farm machines under the hiring scheme have BEP less than their annual operating days and uses i.e. the net annual usage of machinery after the BEP is positive (where the net annual usage = adopted annual operating days/ year – BEP of machinery). If the net annual usage is positive, the hiring of that machine is positive.

At present hiring rates endorsed by government for the Farm Machinery Corporation Limited (FMCL) is positive and can make profit as shown in Table 3. The graph of annual profit or loss is plotted as shown in Figure 10. From it, it is observed that tractors and combine harvesters make maximum profits annually at the present endorsed parameters. A tractor alone makes a profit of around Nu. 0.5 million in a year. Other machines are all making profit, which is good for the hiring scheme as shown.

Table 3. Breakeven point analysis of farm machines

Parameters	Power tiller	Tractor above 34hp	Tractor 34hp	Tractor 18hp	Paddy reaper	Combine harvester	Paddy Transplanter	Water pump	Mini Tiller
Initial Cost (Nu)	302,839	1,300,000	1,000,000	800,000	130,000	1,300,000	150,000	252,927	257,000
Operating days /year	70	70	70	70	20	50	20	30	50
Actual operation cost/day (Nu)	3376	12044	9018	7000	4427	13179	4900	3301	3862
Breakeven Point (days/year)	22.6	27.9	28.4	29.0	9.2	20.3	9.4	14.1	15.8

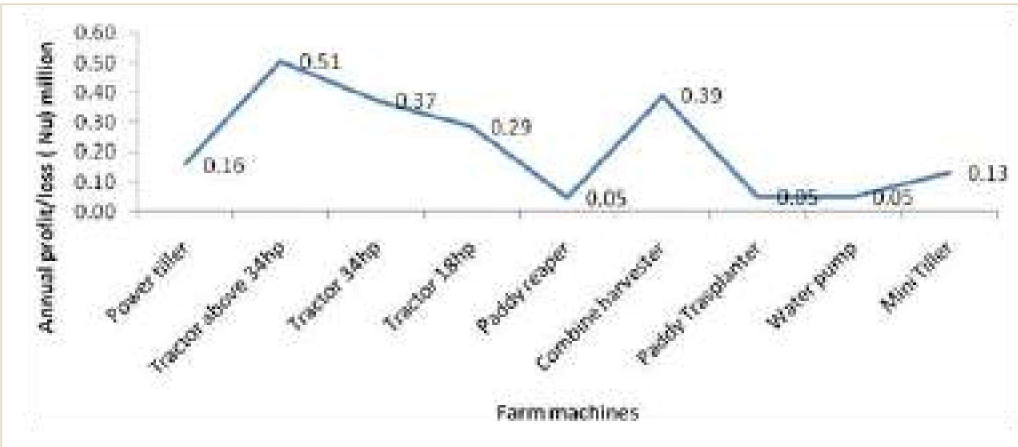

Figure10. Annual profit/loss of various common machines

Private hiring services also prevail very effectively although net amount of the charges on the farmers are double of the FMCL's rates. There is the potential for reducing the custom hiring rates specifically for these machines by reducing the subsidy components to encourage the private sector participation eventually. The income generation situation further improves for machines like tractors, in case the number of working days per year includes those for non-agricultural purposes.

3.3. Subsidy support from government

Table 4: Subsidy component from government side for hiring

Description	Power tiller	Tractor above 34hp	Tractor 34hp	Tractor 18hp	Paddy reaper	Combine harvester	Paddy Transplant	Water pump	Mini Tiller
Custom hiring rate to farmers	1500.00	3800.00	2900.00	2300.00	2200.00	4400.00	1300.00	2500.00	1300.00
Custom hiring rate	3376.00	12044.00	9018.00	7000.00	4427.00	13179.00	4900.00	3301.00	3862.00
Subsidy from Government (%)	55.57	68.45	67.84	67.14	50.31	66.61	73.47	24.26	66.34

The government is promoting this hiring system in a very concerted effort which can be clearly visible through the subsidy percentage. For major machines, the subsidy is more than 55% which is indeed very good in one hand and also high considering the private hire services are also availed by farmers without subsidies.

4. Conclusion

The analyses give a positive outlook for machine owners and FMCL to take up hiring scheme as it is still very profitable based on the nationally endorsed parameters. The custom hiring rates also provide a useful guide on the custom hiring rates to be charged based on the operating days.

With the present endorsed hiring rates and parameters adopted for assessment by the government, the FMCL is making substantial profit especially through the hiring of tractors and combine harvesters. This is a potential scope for business for any enterprise wanting to venture into this sector. However, there is also an opportunity to reduce the total custom rates to bring down the overall cost of farming as the private rates for similar machines are still low.

Acknowledgement

The author would like to acknowledge colleagues of AMC for making available the endorsed parameters of the government. The author would also like to acknowledge AMC, FMCL and Department of Agriculture officials who had participated in the endorsement of the parameters, which helped the author to further analyse and submit the observations with recommendations to the government.

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Assessment of Soil Fertility Status using Soil Nutrient Index in Three Landuse Systems in Bhutan

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ABSTRACT

The study was conducted to assess soil fertility status using soil nutrient index in three land use systems (dryland, wetland and orchard) in Bhutan. The total number of soil samples varied from 71 to 836 depending on soil variables. Soil samples were collected from three different land uses between July 2013 to December 2018, and analyzed, interpreted for pH, organic carbon, organic matter, primary nutrients, carbon/nitrogen ratio, total exchangeable bases, cation exchange capacity and base saturation. The data on soil variables were categorized into very low, low, medium, high and very high classes based on soil fertility ratings and nutrient index. The results revealed that soil reaction in three different land uses varied from strongly acidic to slightly alkaline with pH values varying from 4.04 to 8.20. Soil fertility with respect to organic matter was high in dryland and medium in others. In all the land uses, status of nitrogen was low, organic carbon in medium and CN ratio in good category. The level of available phosphorous and cation exchange capacity was medium in dryland and orchard but low in wetland. Available potassium and exchangeable bases were medium in dryland and low in others. Base saturation was in low category in orchard and medium in other two land uses. A positive and significant correlation of organic matter was found with nitrogen, potassium and cation exchange capacity while significant negative correlations existed between soil pH and nitrogen, organic matter and cation exchange capacity. Based on the criteria for calculating nutrient index value, besides low content of nitrogen in dryland, the soil fertility was characterized as medium in dryland, low in wetland and low - medium category in orchard.

Keywords: *Soil fertility, Soil nutrient Index, Land use*

1. Introduction

Soil is the fundamental and most important natural resource which takes long time to renew. Soil fertility is a dynamic natural property that can change through the impact of natural and anthropogenic factors (Kavitha & Sujatha, 2015). With the increase in human population, disturbance on the earth's ecosystem and soils to produce more food and fiber will place greater demand on soils to supply essential nutrients. Intensive cropping for enhanced yield removes substantial amounts of nutrients from soil. Imbalanced and inadequate use of chemical fertilizers, improper irrigation and various cultural practices also deplete the soil quality rapidly (Medhe,

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Tankankhar, & Salve, 2012). Soil fertility alters throughout the crop season each year due to change in the quantity and availability of mineral nutrients and crop uptake. Hence, evaluation of fertility status of the soils of an area or a region is an important aspect in the context of sustainable agriculture (Singh & Mishra, 2012). Soil testing assesses the current fertility status and provides information regarding nutrient availability in soils which forms the basis for sustainable soil fertilizer management for maximizing crop yields and to sustain optimum soil health. For proper soil fertility management, farmers should know what amendments are necessary to optimize the productivity of soil. Currently, information on soil fertility status of different land use in Bhutan is lacking. Hence, this study focuses on assessment of soil fertility status using nutrient index approach in three predominant land uses systems (dryland, wetland, and orchard) in Bhutan.

2. Materials and Method

The National Soil Services Centre (NSSC), Department of Agriculture, Ministry of Agriculture and Forests (MoAF), Bhutan, conducted several Farmer-Extension Use Fertilizer Trials (FEFUT) especially in rice, wheat and potato. Long term studies on potato, maize and citrus were also carried out. Several soil fertility investigations were conducted across the country. The soil samples collected during the field work from different land use were analyzed in Soil and Plant Analysis Laboratory (SPAL) of the NSSC. The soil nutrient data pertains to the field work carried out from July 2013 to December 2018.

2.1 Soil sampling

Soil samples collections from dryland, wetland and orchard are explained below:

i) The selected dryland and wetland plots were divided into 8-10 parts in random to represent the total area. Soil samples from minimum of 8-10 points were collected at a depth of 20 cm using soil augur. Soil samples were mixed together to form one composite sample of 1 kg. The soil was then sealed in plastic bag with proper level indicating name, location and plot size.

ii) Soil samples from citrus and apple orchards were taken from 8-10 randomly selected point from the orchard. The orchards were divided into at least 8-10 parts in random for an area of not more than 1 ha. Following the tree canopy, soil samples from minimum of 8-10 parts were collected at a depth 15 cm representing top soil and 40 cm representing sub-soils from the same pit using soil augur. Samples were mixed separately to form two composite samples, top and sub soil respectively. The composite sample of 1 kg was sealed in plastic bag with proper level indicating name, location and plot size.

2.2 Laboratory Analyses

The soil samples were analyzed at Soil and Plant Analytical Laboratory (SPAL) under NSSC. The plant nutrient parameters analyzed were pH, organic carbon (OM), total nitrogen (N), available phosphorous (P), available potassium (K), cation exchange capacity (CEC) and base saturation (BS) using standard analytical method. Soil reaction (pH) was determined by using 1:2.5 (g/v) soils: water suspension with the calibrated pH meter (Black, 1965). OM was determined by oxidizing at a temperature of approximately 120° C with a mixture of potassium dichromate and concentrated sulphuric acid following wet combustion method of Walkley and Black (1934). Exchangeable cations (BS) (Viz., Ca^{2+} , Mg^{2+}, Na^{+}, and K^{+}) were determined directly in a 1.0 mole neutral ammonium acetate filtrate using flame photometer for sodium and potassium and atomic absorption spectrometer (AAS) for calcium and magnesium as described by Black (1965). Total N was determined by semi micro Kjeldahj method using segmented flow analyser as described by Black (1965), Krom (1980) and Verdouw, Van Echteld and Dekkers (1977). Available K was extracted using $CaCl_2$ solution and the extract potassium was determined using flame photometer as described by Steele, Ramsey and Kanel (1984). Available P was determined by Bray I method using segmented flow analyzer as described by Bray and Kurtz (1945). CEC was determined using ammonium acetate at pH <7.5 and analyzed through segmented flow analyzer as described by Black (1965), Krom (1980) and Verdouw et al (1977). Moisture content was determined by drying the soil sample overnight at 105° C. The moisture correction factor was calculated from moisture content.

2.3 Soil fertility rating chart

The fertility status of the soils, different soil physio-chemical properties were classified based on the soil nutrient status rating class as given in Table 1.

Table 1. The soil analysis result: very low, low, medium, high and very high

Soil variables	Very low	low	Medium	High	Very high
pH(H20)	<4.5	4.6.5.5	5.6-6.5	6.6-7.5	>7.5
N%	<0.1	0.1-0.19	0.2-0.49	0.5-0.99	>1.0
OC%	<0.6	0.6-1.1	1.2-3.0	3.1-4.9	>5.0
OM%	1.00	1.90	5.20	8.43	>8.43
C:N ratio	9.9	10-14.9	15-19.9	20-49.9	>50
Av. P (mg/kg)	<5	5-14.9	15-29.9	>30	
Av.K (mg/kg)	<40	40-99	100-199	200-299	>300
ExBases (me/100g)	<3	3.0.74	7.5-14.9	15-29.9	>30
CEC (me/100g)	<5	5-14.9	15-24.9	25-39.9	>40
BS%	<35	35-49.9	50-64.9	65-79.9	>80

Source: RGoB/DASA, 1995 as modified by BSS 2001.
Where, N%= Total nitrogen percent; OC% = organic carbon percent; OM%= organic matter percent; C:N= carbon: nitrogen ratio; Av. P = available phosphorous; Av. K= available potassium; ExBases = total exchangeable bases; CEC = cation exchange capacity; BS% = base saturation percent

2.4 Nutrient index value

In order to compare the levels of soil fertility of one area with those of another it is necessary to obtain a single value for each nutrient (Denis, Patel, Kamara, & Saidu, 2016). The nutrient index introduced by Parker, Nelson, winters and Miles (1951), modified by Pathak (2010) and Kumar et al. (2013) was used. The nutrient index is a three tier system used to evaluate the fertility status of soils based on the percentage of samples in each of the three classes, i.e., low, medium and high and multiplied by 1, 2 and 3 respectively. The sum of the figures thus obtained is divided by 100 to give the index or weighted average as given in the equation below:

$$Nutrient\ Index = \{(1xA) + (2xB) + (3xC)\} \div TNS$$

Where A = Number of samples in low category; B = Number of samples in medium category; C = Number of samples in high category, TNS= Total number of samples. The rating chart is given in table 3.

Table 2. Nutrient index with range and remarks

Nutrient index	Range	Remarks
I	>1.67	Low
II	1.67-2.33	Medium
III	<2.33	High

Source: Evaluation of soil fertility status in various agro ecosystems of Thrissur district, Kerala, India. International Journal of Agriculture and Crop Sciences

2.5 Statistical Analyses

Descriptive statistics in the form of mean, minimum, maximum, standard deviation, standard error were determined. Correlation was analyzed using SPSS software version 16.0.

3. Results and Discussion

The number of soil samples assessed to study the soil fertility status using soil nutrient index for different land use are presented in Table 3.

Table 3. Number of soil samples evaluated to assess the soil fertility status using SNI for different land types

Soil Variables	Dry land	Wet land	Orchard
	No of soil samples		
pH($H_2$0)	591	414	836
N%	591	212	836
C%	591	212	828
OM%	591	404	836
C:N ratio	525	404	816
Av. P (mg/kg)	591	413	836
Av.K (mg/kg)	591	414	835
ExBases (me/100g)	205	71	664
CEC (me/100g)	206	273	641
BS%	205	273	678

Where, N%= Total nitrogen percent; OC% = organic carbon percent; OM%= organic matter percent; C:N= carbon: nitrogen ratio; Av. P = available phosphorous; Av. K= available potassium; ExBases = total exchangeable bases; CEC = cation exchange capacity; BS% = base saturation percent

Table 4. Descriptive statistics of soil variables in three landuse

Land use	Soil variables	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Dryland	pH(H20)	5.87	0.59	0.024	4.49	8.01
	N%	0.25	0.10	0.004	0.06	0.90
	OC%	2.88	1.27	0.052	0.10	7.00
	OM%	4.93	2.21	0.091	0.12	12.04
	C:N ratio	12.56	5.45	0.224	0.37	44.29
	Av. P (mg/kg)	38.28	43.85	1.804	0.05	318.54
	Av.K (mg/kg)	171.29	90.85	3.737	4.30	613.80
	ExBases (me/100g)	11.85	5.258	0.357	1.86	36.39
	CEC (me/100g)	21.44	7.03	0.490	2.14	45.14
	BS%	58.87	49.28	3.442	9.31	701.65
Wetland	pH(H20)	5.77	0.74	0.036	4.49	8.16
	N%	0.13	0.07	0.005	0.01	0.35
	C%	1.59	0.787	0.054	0.06	4.50
	OM%	2.58	1.20	0.060	0.10	7.74
	C:N ratio	13.33	8.86	0.440	0.43	89.53
	Av. P (mg/kg)	22.84	35.037	1.720	0.05	216.50
	Av.K (mg/kg)	75.60	81.449	4.000	0.05	630.0
	ExBases (me/100g)	5.01	4.77	0.566	0.13	15.42
	CEC (me/100g)	10.53	4.26	0.258	2.80	32.0
	BS%	65.23	37.20	2.251	2.43	169.60
Orchard	pH(H20)	5.57	0.72	0.020	4.04	8.20
	N%	0.22	0.14	0.005	0.01	1.40
	C%	2.32	1.02	0.040	0.01	6.70
	OM%	3.95	1.77	0.060	0.02	11.52
	C:N ratio	12.87	8.55	0.300	0.13	92.00
	Av. P (mg/kg)	38.68	68.19	2.360	0.03	566.85
	Av.K (mg/kg)	93.49	71.37	2.470	0.05	462.12
	ExBases (me/100g)	7.32	4.73	0.180	0.47	27.39
	CEC (me/100g)	20.18	7.80	0.310	0.04	53.26
	BS%	39.96	29.87	1.15	1.91	318.14

3.1 Soil reaction (pH)

The pH of the soils of three land uses ranged from 4.04 to 8.20 indicating extremely acid to alkaline (Table 4). On assessing the soil acidity, it was found that 61% of samples were within medium range of soil reaction in dryland, 37.7% in wetland and 47% in orchard. Only less than 1% of the samples were within extremely acid range in dryland and wetland and 5% in orchard. Wetland had the maximum number of soil samples within alkaline range with 2.42%, 1.2% in orchard and 0.68% in dryland respectively (Figure 1). The mean value of the soil samples analyzed were in medium range (5.74), slightly acidic in nature. This could be due to prevailing geology which is dominated by granitic genesis in the north and phyllite schist in the south (Norbu & Floyd, 2001) which produce acid and acidity is aggravated due to leaching and soil erosion which washes alkaline elements (calcium, magnesium, sodium and potassium) away (Bradford, 2014).

3.2 Organic carbon (OC)

The OC percent of the three land uses varied from 0.01 to 7.0 (Table 4) with average of 2.26. Wetland had the maximum number of soil samples within low range (28.78%), orchard (9.42%) and dryland (6.6%). Medium to high level of OC was observed in orchard (88.16%), dryland (84.44%) and in wetland (71.22%) (Figure 1).

3.3 Organic matter (OM)

The OM percent of three land uses varied from 0.02 to 12.04 (Table 4) indicating very low to very high OM content in the soil. High to very high level of OM was observed in dryland (42.47%) followed by orchard (21.31%) and wetland (4.7%).Wetland had the maximum number of soil samples with low level of OC (28.78%) and OM (32.67%) (Figure 1). The low levels of OC and OM in wetland may be due to less usage of organic manure in major rice growing dzongkhags (Yeshey, Bajgai, & Ghimiray, 2014).

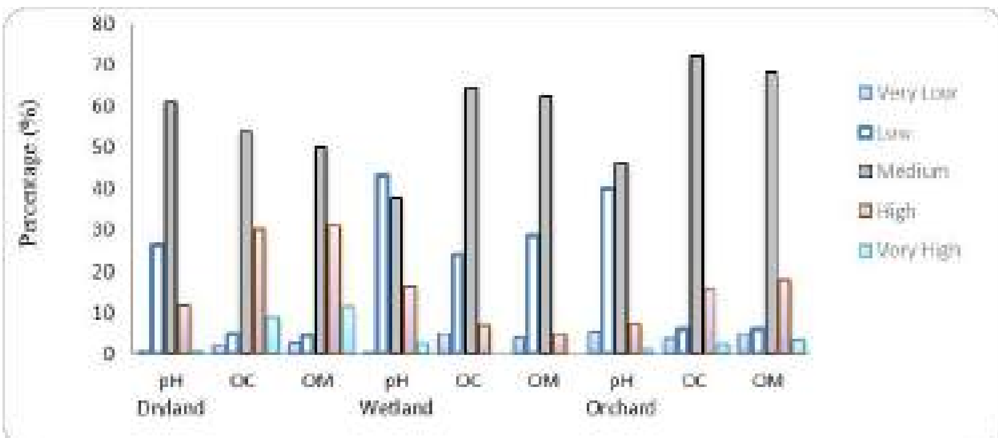

Figure 1. % pH, organic carbon and organic matter of dryland, wetland and orchard

3.4 Total Nitrogen (N)

The N percent of the soils of three land uses varied from 0.01 to 0.09 (Table 4) with a mean value of 0.2. The means of dry land and orchard was higher than the mean of wet land (0.13). The low level of N content in wetland soils could be due to low level of OM (32.67%) (Figure 2), since OM is one of the main sources of N requirement of the crops (Kavitha & Sujata, 2015). Out of cumulative total of 1639 soil samples analyzed for N, only 2.86% of the soils were observed within very high to high range, 48.63% within medium range and 48.51% within low to very low range. The low level of N content may be related to soil management and moreover N content in soils is dependent on temperature, rainfall and altitude. In addition, continuous and intensive cultivation leading to high crop removal together with insufficient replenishment could be the reason for high degree of N deficiency in these soils (Denis et al., 2016).

3.5 Phosphorous (P)

The P level of the soils of three land uses varied from 0.03 – 318.54 mg/kg (Table 4) with average P of 33.27. Wetland had the maximum number of soil samples (62.96%) within very low to low range, followed by orchard (50.24%) and dryland (40.44%) respectively. Excess level of P content in dryland (40.61%) wetland (20.58%) and in orchard (33.25%) was also observed (Figure 2). Due to acidic nature of the soils, phosphate ions react with aluminum and iron to form less soluble compounds (Jensen, 2010) and with imbalanced usage of phosphatic fertilizer over a period of time, phosphate level could have built up in the soils resulting in excess levels. Excess level of P in the soil not only impairs the availability and uptake of essential nutrients by plants but also leads to soil and water pollution (Kavitha & Sujata, 2015).

3.6 Potassium (K)

The K level of the soils of three land uses varied from 0.05 – 630 mg/kg (Table 4) indicating very low to very high K content (Table 4) with average of 113.46 mg/kg. The K deficiency level was low in dryland (21.15%), high in orchard (64.07%) and in wetland (73.91%) (Figure 2). The low content of K in orchard soils might be due to the low use of K containing fertilizers especially in citrus (NSSC 2013). The probable reason for low level of K in wetland could be due to leaching condition brought in by irrigation coupled with soil acidity which does not permit retention of potassium on the soil exchangeable complex (Kavitha & Sujata, 2015). Medium to high K content was recorded in dryland (78.85%), wetland (26.09) and in orchard (35.93%) (Figure 2). The low level of K content is not much of concern as soil parent materials are generally K rich (Norbu & Floyd 2001).

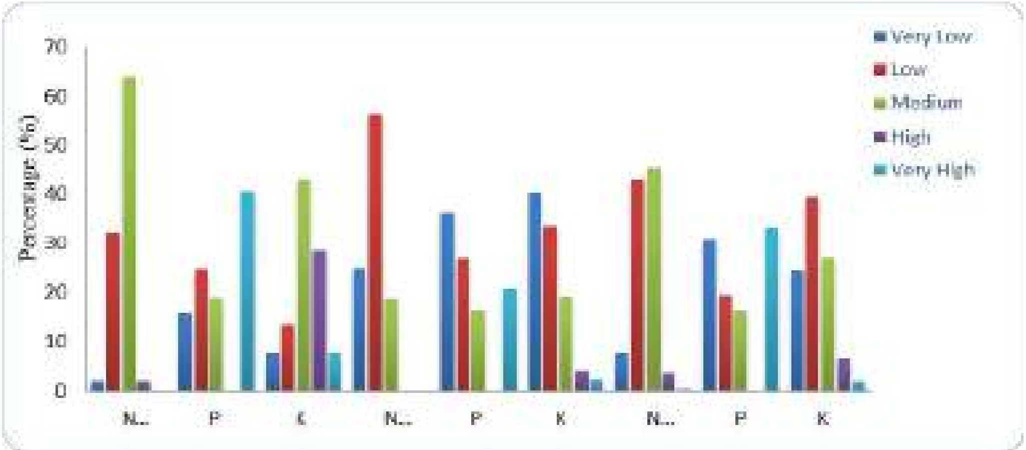

Figure 2. % N, P, K content of dryland, wetland and orchard

3.7 C/N ratio (CN)

The level of CN ratio varied from 0.13 to 92 (Table 4) with average of 12.92 in the soils of three land uses. The CN was within good to very good range in all land uses (Figure 3) probably due to good OC and low level of N content.

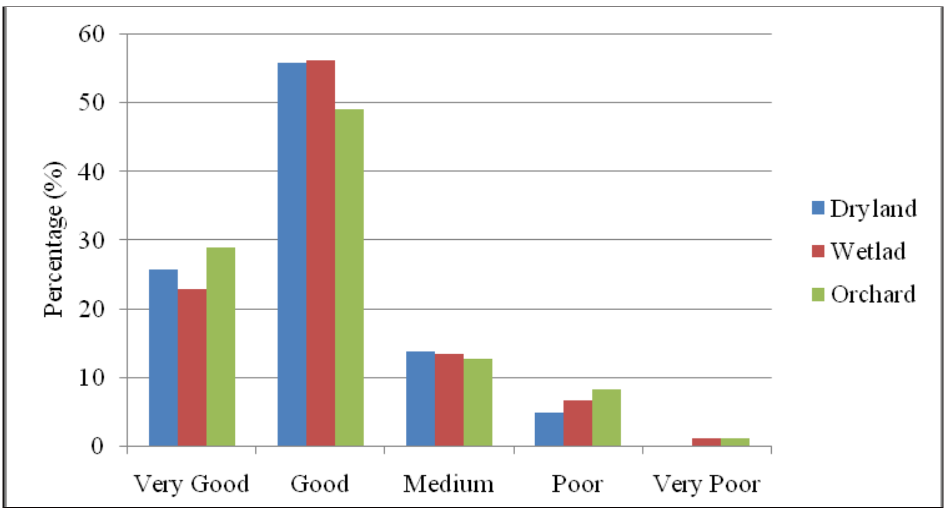

Figure 3. % CN content of soils of three landuse

3.8 Exchange

The Exbases (calcium, magnesium, potassium and sodium) of the soils ranged from 0.13 to 36.39 me/100g (Table 4) with average of 8.06. The levels of Exbases were within medium to high in dryland (81.47%), orchard (43.68) and in wetland (39.44%) (Figure 4).

3.9 Cation exchange capacity (CEC)

The CEC of the soils of three land uses ranged from 0.04 to 53.26 (Table 4) indicating very low to very high ability of the soil to hold or store exchangeable cations. On assessing the soil CEC, it was found that 86.06% of samples were within very low to low range in wetland, 28.7% in orchard and 20.87% in dryland. Dryland had the maximum number of soil samples within medium to high range with 81.47%, 70.36% in orchard and 13.92% in wetland respectively (Figure 4). The mean values of the soil samples analyzed were within medium range (17.38%). The probable reason for low CEC in wetland could be due to less content of OM (32.67%) and soil acidity with pH >5.5 (39%) and leaching of cations especially in rice growing area.

3.10 Base saturation (BS)

The BS percent of the soils of three land uses ranged from 1.91 to 701.65 (Table 4) with mean of 54.69. The level of BS of the soils varied from very low to medium in orchard (85.99%), dryland (68.78%) and in wetland (49.09%). Maximum number of soil samples having high BS was recorded in wetland with 50.91%, 31.22% in dryland and 14.01% in orchard (Figure 4). BS and pH are positively correlated; low pH would have low BS (Leticia 2017) that could be the reason having maximum soil samples within very low to medium range. The variations in the level of BS in wetland with 50.91% of soil samples within high range could be due to less number (n=273) of soil samples interpreted for BS as compared to pH (n=414).

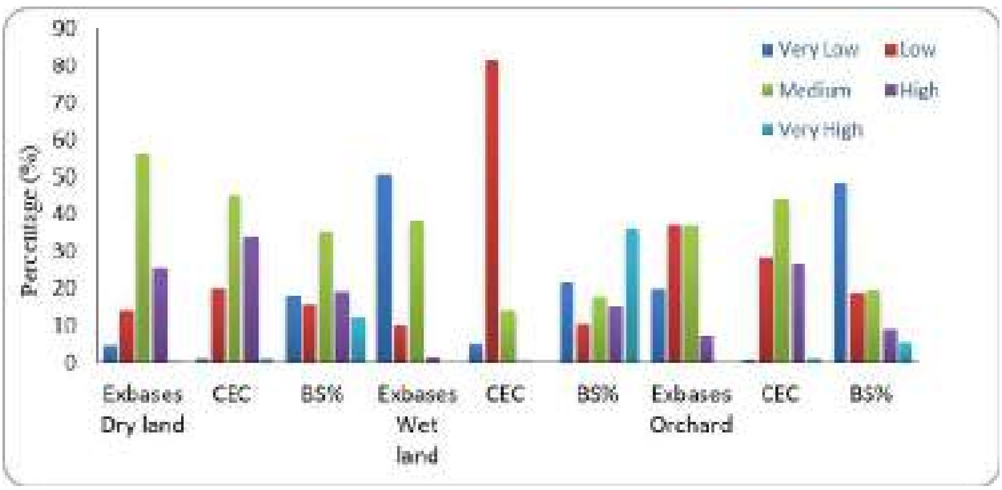

Figure 4. % Exbases, CEC, BS content of dryland, wetland and orchard

3.11 Relationship among selected soil variables

The soil pH exhibited significant but negative correlation with N and CEC, negative and non-significant correlation with OM. N was significantly correlated with OM, K, CEC, but negatively correlated with BS which was non-significant. Negative correlation was also observed between

N and P at significant level. OM was significantly correlated with K and CEC but negative and significant correlation was recorded with P and BS. Available P was significantly correlated with K and BS, and negative non-significant correlation was observed with CEC but significant negative correlation was recorded with N. Available K was significantly correlated with all soil variables. CEC and BS were negatively correlated at significant level (Table 5). Negative and significant correlation between soil pH and N indicated that an increase in soil pH decreases N, which might be due to volatilization loss of N with rise of soil pH (Bhat et al., 2017). Similar results were also reported by Khokhar et al. (2012) and Patil, Saler and Gaikwad (2015) indicating significant and negative correlation between soil pH and N.

Soil Variables	pH	N	OM	P	K	CEC	BS
pH	1	-.072**	-.033	.115**	.404**	-.120**	.552**
N		1	.475**	-.071**	.170**	.382**	-.015
OM			1	-.062**	.220**	.475**	-.142**
P				1	.186**	-.013	.081**
K					1	.221**	.324**
CEC						1	-.301**
BS							1

**significant at the 0.01 level and * the 0.05 level

N%= Total nitrogen percent; OC% = organic carbon percent; OM%= organic matter percent; C:N= carbon: nitrogen ratio; Av. P = available phosphorous; Av. K= available potassium; ExBases = total exchangeable bases; CEC = cation exchange capacity; BS% = base saturation percent

4. Nutrient indices value of three land use

In order to compare the levels of soil fertility of one area with those of another it is necessary to obtain a single value for each nutrient (Denis et al., 2016). Nutrient index value is the measure of nutrient supplying capacity of soil to plants (Singh, Sharma, & Singh, 2016). The soil nutrient index of the three land use was calculated from low, medium and high ratings of soil nutrients. If the index value was less than 1.67, the fertility status was low and the value between 1.67-2.33 was medium. If the value was greater than 2.33, the fertility status was high. Among the three land uses, soil pH was low in orchard and medium in other land uses. In all land uses, a level of total N was low, OC was medium and CN was low. On the other end P fertility status was low in wetland and medium in other land use. Levels of K were medium in dryland and low in other land use. Total Exbases was medium in dryland and low in other land use. The level of CEC was medium in dryland and orchard but low in wetland. BS (calcium, magnesium, sodium and potassium) was low in orchard and medium in other land use (Table 6).

Table 6. Soil nutrient index of three land use

Soil variables	Nutrient Index		
	Dryland	Wetland	Orchard
Nitrogen (%)	1.65	1.19	1.54
Organic carbon (%)	2.33	1.78	2.09
Organic matter (%)	2.35	1.72	2.12
Carbon:Nitrogen ratio	1.23	1.29	1.31
Available Phoshorous (mg/kg)	1.97	1.58	1.83
Available Potassium (mg/kg)	2.15	1.33	1.45
Total Exchangeable Bases (me/100g)	2.03	1.41	1.51
Cation exchange capacity (me/100g)	2.14	1.14	1.99
Base saturation (%)	1.98	2.19	1.47

Table 7. Soil fertility rating based on soil nutrient index of three land use

Land use	Soil variables								
	N (%)	OC(%)	OM%	C:N	Av. P	Av. K	Exbases	CEC	BS (%)
Dryland	L	M	H	L	M	M	M	M	M
Wetland	L	M	M	L	L	L	L	L	M
Orchard	L	M	M	L	M	L	L	M	L

L=Low, M=Medium, H=High

5. Conclusion

Based on the criteria for calculating nutrient index value, besides low content of nitrogen in dry land, the soil fertility was characterized as medium in dryland, low in wetland and low - medium category in orchard. The nutrient index value of soil pH ranged from low to medium, the mean pH value of three land use were slightly acidic (<5.6), which may not be a serious problem, since nutrients are moderately available to plants within pH level of 5.5 to 6.5 (Kavitha & Sujata, 2015). Among the different land use, status of OM was high in dryland. Deficiency of N was observed in all land uses. The level of C/N ratio was low within good range, good for crop production since low C/N ratio allows faster decomposition of OM and the release of excess available nitrogen in the soil for growing plants. Deficiency of P, K, Exbases, and CEC were observed in wetland where as the level of these soil variables were in medium category in dryland but in orchard, the level of P and CEC was medium, and K and Exbases were in low category. The level of OC was in medium category in all land uses; however, deficiency of BS was noted in orchard.

Recommendation

Although pH of the soil reaction was within medium range (<5.5) where nutrients are moderately available, improving soil quality of acid soils by liming to adjust pH could increase nutrient availability, improve soil structure, improve microbial activity and improve symbiotic nitrogen fixation by legumes.

Based on the low level of total nitrogen, it is recommended to use more organic manure to improve soil organic matter to increase N content of the soils and reduce chemical fertilizer especially urea application (N fertilizer) and also to improve CN ratio and CEC of the soils.

In all landuse systems, there is an urgent need to enhance recommended dose of nutrients to improve soil fertility. In addition, these studies also provide some soil research needs such as relationship between increasing pH and declining N and build up of OC and CN with regard to different cropping practices.

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Assessment of Soil Nutrients Status of Mandarin Orchards in Dagana

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ABSTRACT

Mandarin is an important fruit crop for Bhutan's economy. In 2017, 38.28% of income earned from the sale of fruits was from mandarin. Mandarin is cultivated in 17 districts of Bhutan. Dagana district in west central Bhutan is an important mandarin growing district. The productivity of mandarin trees in Dagana is low as compared to other districts. In 2017, a mandarin tree which has at least attained three years of age and started bearing fruits of economic value on an average yielded 39 kg of fruits in Dagana, whereas a mandarin tree in Trashigang on an average yielded 81 kg of fruits.There is a scope of improving productivity of mandarin trees in Dagana. One way to improve productivity of the plant is through balanced manuring and fertilization at right time as plant productivity is directly linked with soil fertility level in the orchard. Mandarin performs best in sandy loam soils with pH ranging from 5.5 to 6.5. Generally, soils with low nutrient content will have high response to fertilizer application than soil with high nutrient content. In order to study the soil fertility level in mandarin orchards of Dagana, five important mandarins growing gewogs in the district namely Drugyegang, Trashiding, Tsendagang, Goshi and Kana were selected. Soil sampling was done in those pilot gewogs to study the status of important soil parameters in orchard. Eighty composite soil samples consisting forty top soils and forty subsoil were collected from five pilot gewogs. From each gewog, sixteen composite samples were collected consisting of eight topsoil and eight subsoil from eight different mandarin orchards. Top and subsoil samples were collected from 0-20 cm and 20-40 cm depth respectively. Samples were analyzed and soil fertility level among five gewogs was compared followed which fertilizer recommendations were drawn. Analysis results showed that in general, the soil pH was moderate to slightly acidic, percent carbon at medium level, nitrogen at low level, available phosphorus at high level, available potassium at medium level and cation exchange capacity at low level. The most common soil texture was sandy loam. It could be concluded that the improvement in the level of percent carbon, nitrogen and potassium in soil could improve the productivity of mandarin in Dagana.

Keywords: *Percent carbon, Nitrogen, Available potassium, Soil texture, Cation exchange capacity*

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1. Introduction

Mandarin (*Citrus reticulata* Blanco) is the most important fruit crop in Bhutan as 60% of the population is involved in its cultivation and mandarin is grown in 17 out of the 20 districts in Bhutan (Joshi & Gurung, 2009). In terms of the percent distribution of agriculture area in Bhutan, mandarin (5%) has the highest agriculture land followed by cardamom (3%), apple (2%) and areca nut (1%) (NSB, 2018). In 2017, it contributed 51.26% to the total fruit production and 38.28% to the total income generated through the sale of fruits both within and outside the country RSD, (RSD, 2017). Dagana district in west central Bhutan contributed most to the total production over the years (RSD, 2017; DoA, 2014, 2015, and 2017). In 2017, 21.63% of the total production was from Dagana (RSD, 2017).

In 2017, the high production of mandarinwas due to the large number of bearing trees with 17.85% of the total bearing trees found in Dagana and not due to the high productivity of the trees as the average yield was only 39 kg/tree in Dagana which is far less than 81 kg/tree obtained in Trashigang (RSD, 2018). Bearing trees refer to mandarin trees which have at least attained three years of age and started producing fruits of economic value. The huge gap between the average mandarin yield of Dagana and the highest average yield obtained in Bhutan shows the scope for improving the productivity of mandarin in Dagana.

Improper and inadequate manuring and fertilization under rain-fed farming aggravated by pests and diseases declined mandarin yield in Bhutan (Tshering, Tshering, Khampa & Tomiyasu, 2008). Soil nutrition affects tree growth, yield, fruit size and quality of mandarin (Hardy et al., 2017). Crowley (2011) highlighted the importance of macronutrients and micronutrients in mandarin production. N-P-K fertilizer application improves overall mandarin growth and development (Boughalleb, Mhamdi & Hajlaoui, 2011) and significantly increases the yield (Hume et al., 1985; Nasreen, Ahmed, Ullah, & Hoque, 2013). Integrated nutrient management (INM) was suggested to optimize mandarin yield and production in Bhutan (Dorji et al., 2016).

The major sources of soil nutrition in Bhutan are manures (organic) and fertilizers (inorganic) in mandarin and their balanced application at the right time can improve productivity of mandarin as plant productivity is directly related to soil fertility level in the orchard (NSSC, 2009). Regular soil testing is important in nutrient management of any crop to obtain optimum yield (Horneck, Sullivan, Owen & Hart, 2011). In order to know the soil fertility status, soil sampling and soil analysis are necessary.

With information on the soil fertility status of the orchard soil, necessary recommendations to improve the soil for improved productivity can be made. Thus, the study was conducted to determine the fertility status which is necessary for soil improvement recommendations to improve the mandarin productivity.

2. Materials and Method

The study was carried out in Dagana, awest central district of Bhutan. Five Gewogs (Drugyegang, Trashiding, Tsendagang, Goshi and Kana) were covered in this study. The soil samples were collected from Drugyegang, Trashiding, Tsendagang, Goshi and Kana as it forms important mandarin growing Gewogs in the district (NSSC, 2005a). The pilot Gewogs were selected in consultation with district agriculture sector. The elevation of sampled area ranges from 500 to 1300 meters above sea level (masl). Eight orchards between 10 to 35 years were selected randomly for soil sampling with help from extension supervisor and orchard owner. Trees in all orchards covered in this study were at fruit bearing stage with a minimum of 20 trees in an orchard.

A total of eighty composite samples consisting of forty topsoil and forty subsoil from the selected mandarin orchards were collected. Each composite sample was formed by minimum of eight sub-samples collected from a location randomly. Topsoil samples were collected from 0-20 cm depth and subsoil from 20-40 cm depth. The soil sampling was done from1stto 15th of February, 2018. The samples were properly packed and sent to Soil and Plant Analytical Laboratory at National Soil Services Centre (NSSC) for analysis. The samples were collected as per the soil sampling guideline provided by NSSC.

Seven important soil properties were analyzed from the soil samples thus collected. Google docs sheets were used for compiling and organizing data and then exported to STAR (Statistical Tool for Agricultural Research), version 2.0.1 International Rice Research Institute. Data analysis was maintained at 95% confidence interval. Soil parameters and methods used for analysis are given in Table1.

Table 1. Method used for soil analysis

Sl. No.	Soil Parameter Analyzed	Method Used for Analysis
1	Soil pH	pH (H_2O) method
2	Percent Carbon	Walkley and Black method
3	Total Nitrogen	Kjeldahl method
4	Available Phosphorus	Bray method
5	Available Potassium	0.01M $CaCl_2$
6	Soil Texture	Hand bolus method
7	Cation Exchange Capacity	eCEC method

3. Results and Discussion

3.1 Soil pH

In general, soils of the five gewogs were moderate to slightly acidic in nature and soil pH values falls in favorable range of 5.5 to 6.5 as given in Table 2.

Table 2. Descriptive statistics for soil pH

Variable	N	Min	Max	Mean	Range	StdDev	SE_Mean	CV
SoilpH	80	4.50	6.69	5.93	2.19	0.4073	0.0455	6.87

The comparison of soil pH among gewogs was done (Figure 1). The soils were moderately acidic (average pH=5.5) in Drugyegang. Goshi and Tsendagang have favorable soil pH (5.5-6.5) for growing mandarin. In Kana and Trashiding, soils are slightly acidic (average pH=6.5).

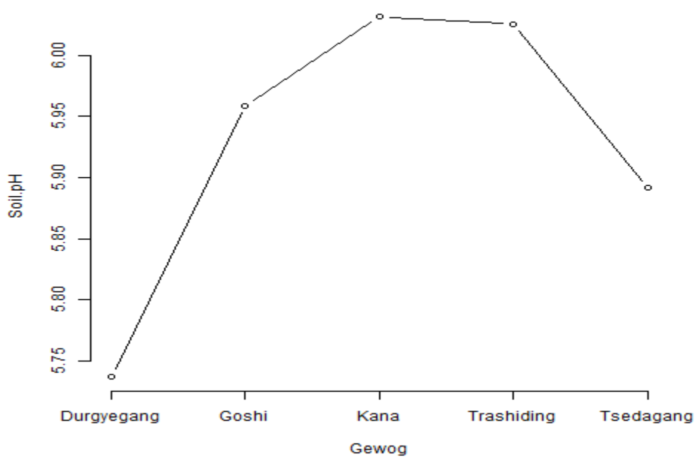

Figure 11. Comparison of soil pH among gewogs

Mandarin does best in soils with pH ranging between 5.5-6.5 as most soil minerals become available for use in that range (Hardy et al., 2017; NSSC, 2005a). It is important to have soil pH in favorable range as it controls nutrient availability and microbial activity in the soil (Espinoza, Slaton & Mozaffari, 2010). National Soil Services Centre (NSSC) also reported the soil pH in all five Gewogs within the range of 5.5-6.5 (NSSC, 2005a). As of now, the mandarin orchards in Dagana have favorable pH for growing mandarin. Extra care must be taken in case of Drugyegang (average pH=5.5), Trashiding and Kana (Average pH=6.5) to maintain the pH in favorable range in years to come. Sandy soils have low amounts of reserve acidity due to low CEC resulting in low soil pH.

3.2 Percent Carbon

In general, the total organic carbon levels were medium as shown in Table 3.

Table 3. Descriptive statistics for percent carbon

Variable	N	Min	Max	Mean	Range	StdDev	SE_Mean	CV
Percent C	80	0.7000	6	2.31	5.30	0.8718	0.0975	37.72

The level of organic carbon was moderate in all five gewogs (Figure 2). Tsendagang had the lowest percent organic carbon levels in soil.

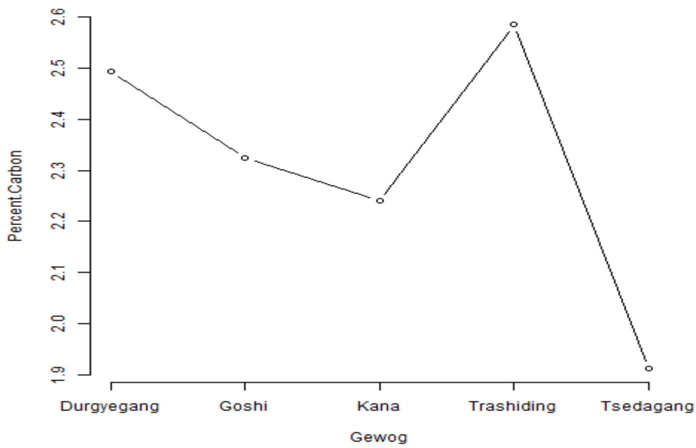

Figure 2. Comparison of percent carbon among gewogs

Soil organic carbon is part of the soil organic matter (SOM), which includes other important elements such as calcium, hydrogen, oxygen, and nitrogen (Espinoza et al., 2010). SOM serves as a reserve for many essential nutrients, especially nitrogen and also influences soil physical, biological and chemical properties (Bolsa Analytical, 2011). The addition of organic matter will supplement nitrogen supply. The low CEC value and sandy loam soil texture could be some of the reasons for the medium levels of organic carbon in Dagana.

Soil organic carbon (SOC) forms about 55-60 % of soil organic matter (SOM). SOM is a surrogate for SOC and reflects the overall soil health (Horneck et al., 2011). SOM forms a reserve for many essential nutrients especially nitrogen and its addition into soil sustain the desirable physical, chemical and biological properties of the agricultural soil (Dinkins, 2013). Soil organic matter has been termed as the lifeblood of the soil (Bianchi, Miyazawa, Oliveira, & Pavan, 2008). Organic matter is critical for biological processes and soil nutrient supply. As a general rule, for every tons of carbon in soil organic matter about 100 kg of nitrogen, 15 kg of phosphorus and 15 kg of sulphur becomes available to plants as the organic matter is broken down (Zhao, He, Huang, Zhang, & Shi, 2016). SOM is critical for retention and release of plant nutrients and sustainable soil management practices that increases SOC in soil should be practiced (Clara et al., 2017/2017).

3.3 Nitrogen

In general, the level of average nitrogen was low in all five gewogs as given in Table 4.

Table 4. Descriptive statistics for nitrogen

Variable	N	Min	Max	Mean	Range	StdDev	SE_Mean	CV
Total N.	80	0.0100	0.3800	0.1730	0.3700	0.0843	0.0843	48.75

The level of nitrogen was observed low in four out of the five Gewogs. The level of nitrogen was lowest in Kana followed by Tsendagang, Trashiding and Drugyegang. Only Goshi gewog had medium level of nitrogen in the soil (Figure 3).

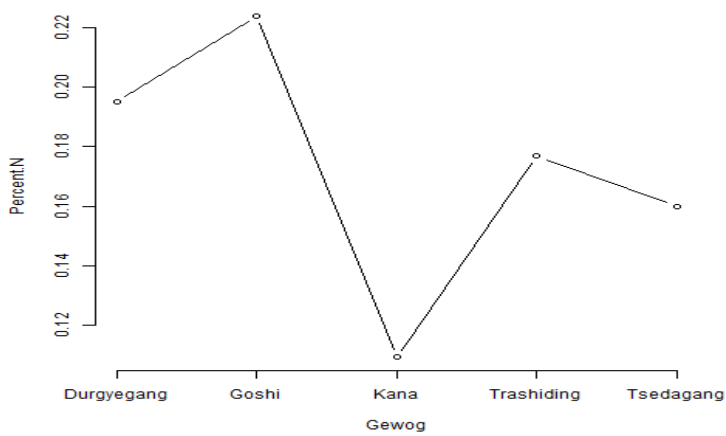

Figure 12. Comparison of total nitrogen among gewogs

Nitrogen forms the major component of the protein and chlorophyll. Tissue nitrogen levels are strongly related to photosynthesis by leaves, and the production of carbohydrates for growth, flowering and fruit development (Crowley, 2011). Hardy et al. (2017) reported high yields of mandarin through management of tree nitrogen supply appropriately and it was also found to have a major impact on fruit quality in combination with P and K. Hume et al. (1985); Wang, Shi, Wei, Yang, & Uoti (2006) also reported significant difference in yield of mandarin through supply of nitrogen. The supply of nitrogen to mandarin promises improvement in productivity. The moderate organic carbon levels and sandy loam soil texture could be reasons for low nitrogen level in Dagana soil.

3.4 Available Phosphorus

In general, the available P levels were high in most soil as shown in table5.

Table 5. Descriptive statistics for available phosphorus

Variable	N	Min	Max	Mean	Range	StdDev	SE_Mean	CV
Available P	80	0.0500	164.70	42.16	164.65	43.31	4.84	102.72

The available phosphorus was found high in Drugyegang soil and medium in four other gewogs (Figure 4).

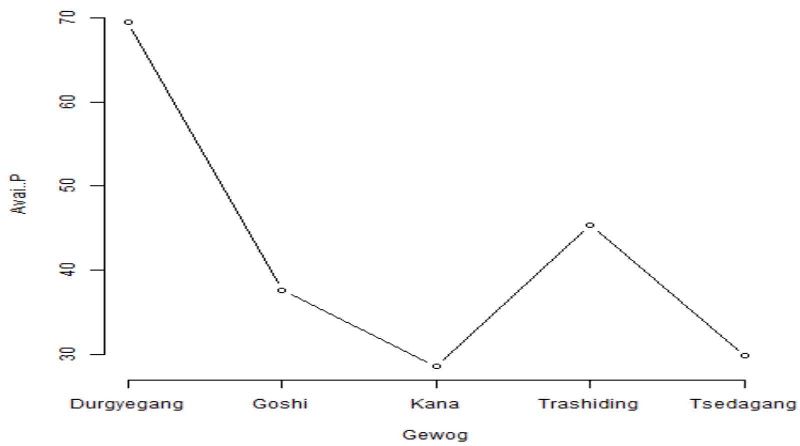

Figure 4. Comparison of available phosphorus among gewogs

Phosphorus plays an important role in plant processes that require energy, including cell division and growth, photosynthesis, sugar and starch formation, and the movement of carbohydrates within the plant (Crowley, 2011). The favorable soil pH could be one reason for its high levels in

Dagana as at pH of 5.5 to 6.5, Phosphorus does not get fixed by elements like aluminum, iron and calcium in soil.

3.5 Available Potassium

In general, available K levels were moderate in most soils as given in table6.

Table 6. Descriptive statistics for available potassium

Variable	N	Min	Max	Mean	Range	StdDev	SE_Mean	CV
Available K	80	31.66	422.69	196.29	164.65	83.80	9.37	42.69

The available K levels were high at Drugyegang and Tsendagang gewogs. The other three gewogs had medium level of available K (Figure 5).

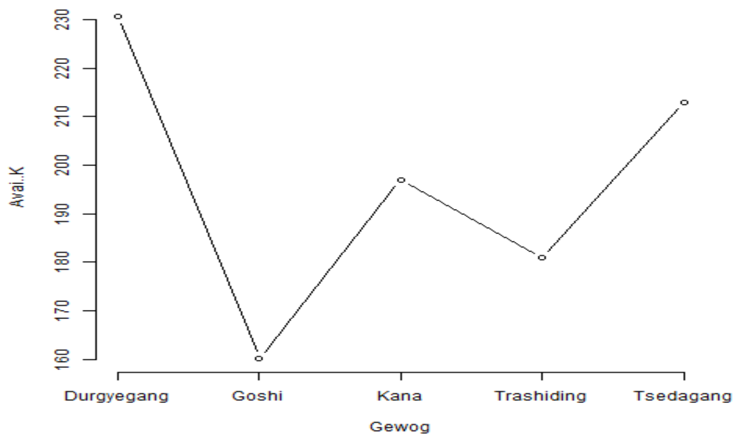

Figure 5. Comparison of available potassium among gewogs

Potassium plays an important role in plant metabolic processes including photosynthesis, protein synthesis and sugar transport and it is needed for cell division and maintaining the balance of salts and water in plant cells (Crowley, 2011). Potassium is the main mineral element in fruit and has more effect on fruit quality than any other element and help trees tolerate stress (e.g. cold and drought) and can improve disease resistance (Nasreen et al., 2013). The addition of potassium fertilizers is essential during fruit development stage (Hardy et al., 2017). Sandy loam soil texture with low organic carbon content could be reasons for medium potassium levels in Dagana as this type of soil has low capacity to hold nutrients.

3.6 Cation Exchange Capacity

In general, CEC were low in most soils as shown in Table 7. Tsendagang had the lowest CEC value (Figure 6).

Table 7. Descriptive statistics for CEC

Variable	N	Min	Max	Mean	Range	StdDev	SE_Mean	CV
CEC	80	2.11	14.37	7.53	12.26	2.85	0.3188	37.85

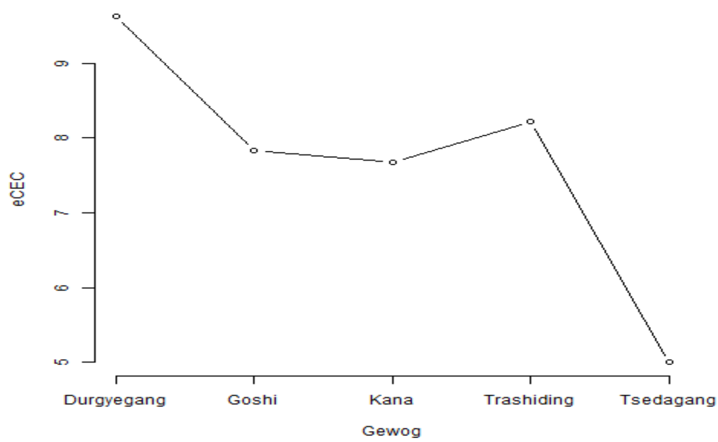

Figure 6. Comparison of eCEC among gewogs

CEC is a measure of the ability of soil to adsorb positively charged nutrient ions (cation) by electrical attraction and generally soil with higher value of CEC will have higher content of clay and organic matter (Bose Analytical, 2011). NSSC (2009) reported low CEC value indicating low content of calcium and magnesium in Dagana soil. The low value could be due to low organic carbon levels in sandy loam soil texture.

3.7 Soil Texture

Sandy loam (SL) was found most common in Dagana region followed by sandy clay (SCL), slit clay (ZCL), loam (L) and loamy sand (LS) and slit loam (ZL) (figure 7).

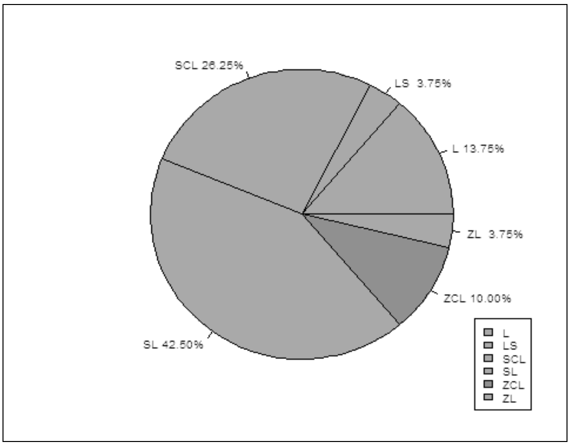

Figure 7. Distribution of soil texture

Soil texture is the relative proportions of sand, slit and clay in the soil and is considered as the permanent soil property. National Soil Services Centre also reported sandy loam (SL) as common soil texture of mandarin orchards in Dagana and recommends sandy loam and loamy soil for mandarin cultivation (NSSC, 2005a). Mandarin does well in sandy soil with proper drainage (Hardy et al., 2017). Orchard soils need to be well drained to prevent tree roots from being subject to waterlogging for prolonged periods. However, it is important to maintain organic carbon level in such type of soil for retention of nutrients and water in soil.

3.8. Key Recommendations to Improve Productivity of Mandarin

The recommendations are drawn based on soil analysis results to improve the productivity of mandarin in Dagana as given in Table 8. For fertility factors (N, P, K) very low and low classifications indicate a high probability for obtaining a fertilizer response; medium classifications indicate a fertilizer response may or may not occur; high and very high classifications indicate a fertilizer response is not likely to occur (NSSC, 2005a, 2009).

Table 8. Recommendations to Improve Productivity

Gewog	Recommendations
Drugyegang	• Soil pH can be increased with liming (12 kg/tree). Apply it after harvest and prior to spring flush. • Integrated nutrient management (INM) can maintain the favorable level of organic carbon (OC) in soil. Well decomposed compost or FYM (2-3 t/acre) is recommended to apply whenever available. • Urea (450 gm. /tree) is recommended. Split application of 150 gm in January-February, May-June and July-October should be practiced.
Trashiding	• Gypsum (8 kg/tree) is recommended to reduce soil pH. Apply it after harvest and prior to spring flush. Avoid using base forming nitrogenous fertilizerslike ammonium sulphate, ammonium chloride, monoammonium phosphate and diaammonium phosphate. • INM can maintain the favorable level of OC in soil. Well decomposed compost or FYM (2-3 t/acre) is recommended to apply whenever available. • Urea (450 gm /tree) is recommended. Split application of 150 gm in January-February, May-June and July-October should be practiced. • Muriate of Potash (MoP) (425 gm /tree) is recommended. Apply it after harvest and prior to spring flush.
Tsendagang	• INM can maintain the favorable level of OC in soil. Well decomposed compost or FYM (2-3 t/acre) is recommended to apply whenever available. • Urea (450 gm. /tree) is recommended. Split application of 150 gm in January-February, May-June and July-October should be practiced.
Goshi	• INM can maintain the favorable level of OC in soil. Well decomposed compost or FYM (2-3 t/acre) is recommended to apply whenever available. • Urea (300 gm /tree) is recommended. Apply split application (150 gm) in January-February and July-October. • MoP (425 gm /tree) is recommended. Apply it after harvest and prior to spring flush.
Kana	• Gypsum (8 kg/tree) is recommended to reduce soil pH. Apply it after harvest and prior to spring flush. Avoid using base forming nitrogenous fertilizers like ammonium sulphate, ammonium chloride, monoammonium phosphate and diaammonium phosphate. • INM can maintain the favorable level of OC in soil. Well decomposed compost or FYM (2-3 t/acre) is recommended to apply whenever available. • Urea (450 gm /tree) is recommended. Split application of 150 gm in January-February, May-June and July-October should be practiced. • MoP (425 gm /tree) is recommended. Apply it after harvest and prior to spring flush.

4. Conclusion

Mandarin as a cash crop plays an important role in Bhutan's economy. Dagana district contributes most in terms of production of mandarin as most bearing trees are situated there. However, the low productivity of trees in the district is a concern and can be improved to achieve higher productivity. The improvement in soil fertility status of the orchard can be one ways to improve its productivity. After soil sampling and analysis, Nitrogen, potassium and organic carbon were found as limiting factors in Dagana soil. The productivity of mandarin trees in the selected gewogs can be significantly improved through supply of nitrogen and potassium with addition of organic matter into soil. Therefore, the supply of nitrogen and potassium in required quantity at the critical point between harvest and bud break stage, summer shoot development stage and during the onset of monsoon could prove crucial in improving its productivity in combination with the addition of well decomposed organic matter.

Acknowledgement

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Evaluation of Green Super Rice (*Oryza sativa* L.) Varieties at ARDC Samtenling

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ABSTRACT

The GSR varieties are designed for low input production systems of rice under changing climate which are suitable to southern Bhutan where low input rice production under rain-fed condition is widespread. Forty GSR varieties for rain-fed condition were introduced from IRRI and were evaluated following standard variety evaluation system of field crops in Bhutan at ARDC Samtenling from 2013 to 2017. Six lines were selected and advanced as best GSR varieties from evaluation over five years. In 2018, an experiment was conducted to evaluate six selected GSR varieties in RCBD with three replications. Bhur Kambja1 – a popular rain-fed variety was used as local check. Results show that there was no significant differences in the grain yield between the test entries although IR 83142-B-60-B showed highest yield of 4.20 MTha^{-1}*. The statistical analysis of yield components also showed no significant differences in the number of productive tillers, number of grains per panicle and days to 50% flowering. However, there was significant variation in panicle length, 1000-grain weight and plant height of the test entries. IR 83142-B-61-B had longest panicle length (24 cm) while Mahsuri had the highest TGW (23.4 gm) among all the test entries. The comparison of length-breadth ratio of grains also showed significant difference between the test entries with all test varieties being slender except Mahsuri which had medium sized grains. There was no significant difference in the maturity period as 50% flowering days of all entries ranged from 95 to 97 days. All the varieties showed consistent yield performance over the years.*

Keywords: *Green Super Rice, Rain-fed ecology, Grain yield, Yield component*

1. Introduction

Rice is one of the most important grains in the world grown by 144 million farm families which makes 25% of world farmers (IRRI, 2016). It is also the most important food for Bhutanese people who derive more than half of their calorie needs from it (Chhogyel, Ghimiray, Gyem, & Dorji, 2016). In 2017, Bhutan produced 86,385 metric tons of paddy from the total harvested area of 51,368 acres (RSD, 2017) with national average yield of 1.6 MT ha^{-1}. Since rice is the most important staple crop in Bhutan the Ministry of Agriculture and Forests (MoAF) gives top

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priority in increasing paddy production through various means of vertical and horizontal expansion of area and productivity.

Agriculture Research and Development Centre (ARDC), Samtenling is involved in evaluation of improved varieties through introduction and promotion in lowland paddy production zones of Bhutan and has so far released five improved varieties. An economic impact assessment of rice research program in Bhutan (Shrestha, 2004) reported that despite having 40% share of rice area, the low altitude zone has contributed only 29% of the increase in rice production. The factors attributed are low yield and low adoption of improved varieties in the region. The low altitude paddy growing areas have potential to make significant contribution to national paddy production through adoption of improved, resistant, and high yielding paddy varieties like GSR (Green Super Rice) varieties. The overall adoption rate of improved varieties in the country is 42% (Ghimiray, 2012) which can be increased through introduction and evaluation of GSR varieties. The research center conducted evaluation trials on GSR varieties which were introduced in Bhutan through INGER (International Network for Genetic Evaluation of Rice) nurseries in 2012 from the International Rice Research Institute (IRRI). ARDC-Samtenling evaluated 40 GSR varieties for their performance in southern Bhutan.

The breeding programme for GSR is a collaborative project between IRRI and the Chinese Academy of Agricultural Sciences. According to Zhang (2007), GSR varieties require less application of inputs like pesticides, fertilizers and water while still achieving continuous yield increase and quality. GSR resilience breeding involves fast-track evaluation and development of varieties to cater to the needs of the different regions incorporating genetic traits of multiple abiotic and biotic stress tolerance without compromising grain yield and quality. Such GSR varieties can fit well into varied rice ecosystems and under changing climatic conditions (Ali, Xu, Gao, & Fontanilla, 2012). Furthermore, Yorobe Jr et al. (2016) made important finding of yield benefits of GSR varieties when there is stress like flooding and they equated these varieties to food security in times of extreme climate events.

GSR varieties evaluated at ARDC are lowland rain-fed varieties. According to Mackill (1996) rain-fed lowland rice is usually transplanted, grown in leveled, bunded fields that are shallowly flooded with rain water. Agriculture in Bhutan remains dominated by rain-fed dryland than wetland farming as most of the water sources are dependent on monsoon rainfalls (CIAT, 2017) and most of the low-altitude southern rice belt falls under rain-fed eco-system (Ghimiray et al., 2008). As per Bhutan’s climate smart agriculture profile (CIAT, 2017) increasing fallow land in rice cultivation is due to the lack of irrigation water which is one of the emerging threats of climate change. Moreover, 27% of total household farmers (RSD, 2017) have insufficient irrigation water. This signifies the importance of research and evaluation of rain-fed varieties like GSR for paddy production which is equated to food security in the country (Chhogyel, Ghimiray, Wangdue, & Bajgai, 2015).

The present study has three main objectives: (a) to identify best GSR varieties which suit the low input rice production systems of southern Bhutan, (b) to enhance rice productivity of southern Bhutan through release and promotion of superior GSR cultivars and (c) to enhance contribution of Southern Bhutan to national rice production through adoption of GSR varieties.

2. Materials and Method

2.1 Evaluation trial site

The evaluation trial was conducted at Agriculture Research and Development Centre, Samtenling, in Sarpangfrom2013 to 2018 (Figure 1). The site is located at 26^0 54’-26’ N latitude and $90^0$25’-26’ E longitude. The site falls under wet sub-tropical agro-ecological zone of Bhutan by latitude with an elevation (<600masl), temperature (Max 35°C, Min12°C) and rainfall (2500-5500mm).

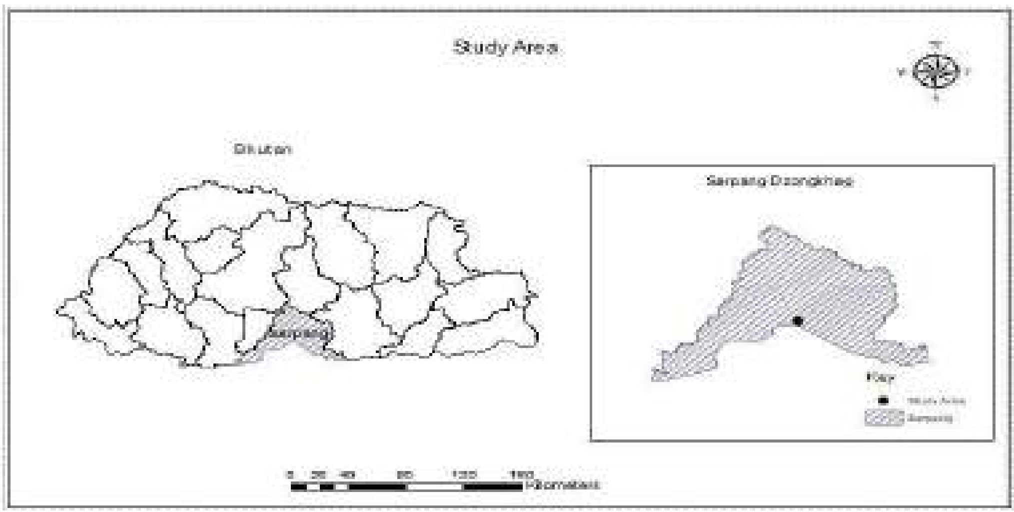

Figure 1. Map of Bhutan showing the study site (ARDC research station) in Sarpang

2.2 Evaluation procedure and methods

The standard variety evaluation system of field crops in Bhutan prescribes evaluation of new materials in Introductory nursery, Observation nursery, Initial Evaluation Trial (IET) and Advanced Evaluation Trials (AET) at research stations. These on-station trials are followed by Pre-production Evaluation Trial (Pre-PET) and Production Evaluation Trial (PET) at farmers’ fields. Introductory nursery was conducted in 2013and Observation nursery in 2014 which were not replicated. Replicated evaluation trials were conducted from 2015(IET), 2016-2017 (AET) using Randomized Complete Block Design (RCBD) with three replications. The data on yield from each replicate was collected and mean yield was calculated. The poor performing lines were discarded in each succeeding year, retaining varieties performing better than the checks. In 2018, as final evaluation in research station, six GSR varieties advanced from various trials were evaluated using RCBD with three replications. A plot size of 10 m^2per treatment was used and BhurKambja1 was used as local check. A spacing of 20 x 20 cm was maintained between plants and rows. Fertilizer dose of 70:40:30 NPK kg ha^{-1} was applied. Half the dose of nitrogen was applied as basal along with full doses of phosphorus and potassium. Another half dose of nitrogen was applied in two splits at active tillering and panicle initiation stages. Two hand weedings were performed at 35 DAT and 65 DAT. Additionally, Butachlor @1.5 a.i. ha^{-1} was applied to control grasses and sedges in the initial stage of crop. The trial was conducted purely under rain-fed condition.

2.3 Weather

Average rainfall and relative humidity recorded during the paddy season from 2013 to 2018 is given in Tables 1a and 1b.

Table 1a.Rainfall data recorded at experimental site during study (NCHM, 2018)

Year	Rainfall (mm)					
	June	July	August	September	October	November
2013	675.0	841.2	1122.1	728.6	12.4	0.0
2014	675.0	841.2	1122.1	728.6	12.4	0.0
2015	1152.8	785.4	1621.3	757.7	62.6	52.0
2016	872.2	2392.0	340.6	1001.6	322.8	0.0
2017	1075.0	923.7	2077.8	1032.0	127.1	11.0
2018	1081.8	813.2	781.6	1100.4	89.1	16.4

Table 1b.Relative humidity data recorded at experimental site during study (NCHM, 2018)

Year	Relative Humidity (%)					
	June	July	August	September	October	November
2013	82.8	88.3	87.8	84.4	78.7	61.5
2014	87.6	84.3	87.1	86.3	67.4	66.5
2015	92.2	85.0	91.1	87.6	72.0	71.1
2016	91.2	93.0	85.5	90.6	80.0	74.9
2017	90.7	89.8	92.9	92.8	79.3	71.5
2018	91.5	89.9	88.8	90.9	76.8	69.4

2.3. Data collection

Data from the field were gathered following Standard Evaluation System for Rice (SES) (IRRI, 2002). The yield of different varieties was collected till 2017. In 2018, data on basic agronomic traits were collected. The experimental plots were monitored at regular intervals and data for plant height were gathered after flowering while agronomic parameters such as number of productive tillers, number of filled grains per panicle, panicle length and yields were measured during the harvesting stage. Calculation of grain yield was done following the standard formula with grain yield adjusted to 14% moisture level at harvest. The research data were compiled in Microsoft Excel spread sheet and were analyzed using statistical software STAR 2.0.1. Analysis of variance (ANOVA) and comparison of treatment means were done.

3. Results and Discussion

Table 2. Comparison of means on agronomic traits of GSR selected varieties 2018

Variety	50% Flowering days	Tillers hill^{-1}	Plant height (cm)	Panicle Length (cm)	L/B Ratio	No. of grains/ panicle (cm)	1000 Grain wt. (g)	Grain yield (t ha^{-1})
6527	96.67	9.83	106.00 a	22.10 ab	4.20 a	136	18.80 e	3.85
Bhur Kambja1	97.50	9.17	106.00 a	20.90 b	3.23 c	143	22.03 b	3.44
Hua 564	95.67	10.33	91.67 cd	22.06 b	3.60 b	144	18.90 e	3.17
IR 83142-B-60-B	96.00	10.67	90.22 d	22.13 ab	3.70 b	154	20.00 d	4.20
IR 83142-B-61-B	97.00	9.33	97.42 bc	24.00 a	3.10 c	151	21.00 c	3.96
Mahsuri	97.33	9.67	103.00 ab	22.70 ab	2.40 d	152	23.40 a	3.40
RC 8	97.17	9.67	86.83 d	22.40 ab	3.10 c	148	21.10 c	3.40
P-Value	0.38	0.709 7	0.0000	0.005	0.0000	0.5998	0.0000	0.0872
CV	1.21	16.78	3.96	2.99	2.36	12.13	0.2783	17.01

In columns, means with same letter are not significantly different at 5% *P*-value

3.1 Effect of GSR varieties on yield components

3.1.1 Plant height

The plant height was measured when the flag leaves were fully expanded at the crop heading stage from the ground to the tip of tallest tiller. There was significant variation in plant height among the entries ranging from 90.22 cm to 106 cm (Table 2). All GSR varieties are shorter than the check variety except 6527 which produced equal height with the check.

Plant height is an important yield component and within certain range, Zhang et al. (2017) found that the plant height is positively correlated to yield in rice. However, lodging problem in tall varieties often reduces yield. According to Yoshida (1981), a short and stiff culm makes the rice plant more lodging resistant and this increased resistance of improved varieties to lodging appears to be the single character most responsible for high yields. However, medium plant height of 105-115 cm was found ideal and acceptable under Bhutanese context (Chhogyel, Lhab & Dorji, 2013) as there is aspect of straw as fodder. Two GSR varieties evaluated showed similar plant height to Bhur Kambja1 which is currently considered as the best improved variety released for the low altitude rice agro-ecosystem (Dendup, Ngawang, & Chhogyel, 2018). Mahsuri and 6527 with plant height 103cm and 106cm respectively should be easily acceptable to the farmers of southern Bhutan based on their height.

3.1.2 Number of productive tillers per hill

Analysis of variance on productive tillers/hill showed no significant differences among the varieties under study. The number of productive tillers ranged from 9.17 to 10.67 per hill which corresponded to Bhur Kambja1 and IR83142-B-60-B respectively. As per the Standard Evaluation System for Rice (IRRI, 2002), Hua 564 and IR 83142-B-60-B showed medium tillering abilitywhile rest of the entries displayed low tillering ability. However,environmental factors can greatly influence the degree of tillering ability.

According to Yoshida (1981), high tillering capacity is desirable for achieving maximum yields in transplanted rice cultivation and further, missing plants due to poor management can be compensated by high tillering varieties. However, as per Peng, Khush and Cassman (1994), too many tillers per hill increases mortality, poorly filled small panicles which reduces the yield, thus, making medium tillering ability varieties desirable. This may be true in the context of southern Bhutan which is evidenced through wide adaptation of Bhur Kambja1 which averages about 9 tillers per hill. All GSR varieties showed statistically similar number of productive tillers with check variety, indicating their acceptability.

3.1.3 1000- grain weight

Data representing 1000-grain weight (Table 2) showed significant variation among the varieties under study conforming to the findings of (Jahan et al., 2018). Mahsuri had highest 1000-grain weight (23.4 g) while 6527 had the lowest (18.8 g) of all test entries. The 1000-grain weight is a stable varietal character because the grain size is rigidly controlled by the size of the hull (Yoshida, 1981). Hence, the significant variation in 1000-grain weight among the entries under evaluation could be attributed as an intrinsic factor which is further reported by Jahan et al.

(2018) that the 1000-grain weight variation is due to different length and width of the seed which are partly controlled by genetic make-up of the genotypes.

3.1.4 Number of grains per panicle

Number of grains per panicle showed no significant differences among the entries; however, five of the six GSR entries produced more number of grains per panicle than the check variety. The number of grains per panicle ranged from 136 to 154 per panicle corresponding to 6527 and IR 83142-B-60-B respectively (Table 2). Number of grains per panicle is one of the components for grain yield and it is one of the targets for breeding program to improve rice yield. However, genetic analysis of number of grains per panicle is difficult as it is controlled by multiple genes and influenced by environmental conditions (Sattari et al., 2015).

3.1.5 Panicle length

The analysis of variance for panicle length of different entries showed significant variation (*P=0.005*) among the test entries. IR 83142-B-61-B had the longest panicle (24 cm) while Bhur Kambja1 had the shortest panicle of 21 cm (Table 2). Other entries showed statistically similar length of panicle. Panicle length determines the number of grains it can hold and consequently, rice yield (Huang et al., 2013) which is further stressed by Liu et al. (2016) as determinants of panicle architecture and yield. Panicle length strongly affects grain number, grain density and rice quality (Wang et al., 2019). Therefore, it is a widely assessed trait in yield-related research. Panicle length of all GSR varieties under study showed relatively longer panicle than the check variety which should be acceptable.

3.1.6 Days to 50 % flowering

There was no statistically significant difference in days to 50% flowering which ranged from 95.67 days to 97.50 days corresponding to Hua 564 and Bhur Kambja1 respectively (Table 2). All the varieties under study showed statistically similar days to 50% flowering which indicated similar maturity duration with the check variety. The growth duration of GSR varieties under evaluation should be acceptable to southern farmers of Bhutan as evidenced through wide adoption of Bhur Kambja1 which matures in 110-120 days. IRRI classifies rice varieties as short duration varieties which mature between 100-120 days, medium duration between 120-140 days and long duration at 160 days or more. Based on this classification, all varieties under evaluation are short duration varieties under ARDC Samtenling condition. These early maturing varieties would enhance vegetable production which is undertaken during winter season in southern Bhutan as early maturing varieties allow intensified cropping (Yoshida, 1981). However, the adoption of early maturing varieties should be in a contiguous area to avoid bird damage.

The other advantage of short duration variety is high water-use efficiency (Yoshida, 1981). The short duration varieties which are efficient in water-use are desirable especially under rain-fed ecology. Furthermore, Chhogyel, Ghimiray and Subedi (2018) reported that rice in Bhutan is particularly vulnerable to climate change due to shorter growing period; hence, short duration GSR varieties are desirable. The maturity duration is more important to Bhutan since the crop has to fit within a single growing period (Dendup et al., 2018). Thus, early maturing GSR varieties coupled with other desired traits would contribute to overall paddy production in southern Bhutan under changing climate.

3.1.7 Length-Breadth (L/B) Ratio

The length by breadth ratio of the entries differed significantly among the varieties under study. The highest value of ratio was recorded for 6527 (l/b=4.2) while lowest corresponded to Mahsuri (l/b=2.4). The coefficient of variation for this trait was 2.36% (Table 2). The length and width of a rice grain are important attributes that determine the class of the rice while the ratio of the length and the width is used internationally to describe the shape and class of the variety (IRRI, 2006). Based on IRRI classification, all the test entries are slender except Mahsuri which is medium.

3.2 Grain Yield

3.2.1 Effect of GSR cultivars on grain yield

The statistical analysis didnot show significant difference in terms of yield among the test entries. However, IR 83142-B-60-B showed highest yield of 4.20t ha^{-1} followed by IR 83142-B-61-B of at 3.96 t ha^{-1}. Three GSR varieties performed better than Bhur Kambja1 in terms of yield (Table 2). The lowest grain yield was recorded by Hua 564 with 3.17 t ha^{-1}.

Grain yield in rice is a complex trait which is ultimate expression of its individual components (Rajeshwari & Nadarajan, 2004) while in a specific environment, yield potential is determined by varietal characteristics and climatic variables such as temperature and solar radiation during the growing season. Thus, the yield potential differs based on location and season. The GSR varieties under ARDC Samtenling showed high yield potential as compared to national productivity of 1.6 tons ha^{-1}. Therefore, GRS varieties have the potential to enhance paddy production in the country.

3.2.2 Grain yield consistency

The yield consistency of GSR varieties and the check variety from 2013 to 2017 is presented in Table 3. Lowest CV for yield was recorded for RC8 (3.57%) which is more stable than other varieties under study. Three varieties RC8, 6527and IR 83142-B-61-B are more consistent in grain yield than the check variety, Bhur kambja1. Mahsuri showed greater variation (CV=31.56%) as the yield in 2013 was comparatively low in comparison to the following years. Despite low yield in the first year (1.43MT ha^{-1}), the variety performed consistently well from 2014 to 2017 with grain yield ranging from (3.20-3.99 MT ha^{-1}). RC8 showed more consistent in grain yield over five years' duration of evaluation. Stability in performance in rice is one of the most desirable prosperities of a genotype to be released as a variety (Joshi, Shrestha, & Bista, 2003). Further, the multi-location trials over the years will validate the yield consistency of GSR varieties under study.

Table 3. Grain yield of six GSR varieties from 2013-2017

Year	Yield t ha^{-1}						
	6527	Hua 564	IR 83142-B-60-B	IR 83142-B-61-B	Mahsuri	RC 8	Bhur Kambja1
2013	4.22	3.82	4.77	4.57	1.43	3.62	3.37
2014	4.01	3.25	4.61	4.01	3.41	3.83	3.82
2015	3.29	2.61	3.12	3.37	3.53	3.62	2.68
2016	3.99	3.78	4.18	3.83	3.99	3.81	3.84
2017	3.37	2.85	4.7	3.38	3.64	3.53	3.29
Mean	3.78	3.26	4.28	3.83	3.20	3.68	3.40
SD*	0.42	0.54	0.69	0.50	1.01	0.13	0.47
CV** (%)	11.07	16.61	16.04	13.01	31.56	3.57	13.96

SD* Standard Deviation, ** Coefficient of Variance

4. Conclusion

The evaluation of Green Super Rice lines at ARDC-Samtenling for last six years showed that GSR varieties have the potential to perform better than existing traditional varieties in wet sub-tropical zone of Bhutan. The GSR varieties are adaptable to low to medium input production system which is prevalent in this region. Based on statistical analysis of variance among the entries, there was no significant variation in terms of number of days to 50% flowering, productive tillers, number of grains per panicle and grain yield. However, there is variation in terms of plant height, panicle length and grain size. The six GSR varieties were selected as elite varieties for southern Bhutan under rain-fed conditions.

However, there is dearth of information on preferences of varieties by the farmers of this region forcing unilateral selection by research station which should not be the case. These entries therefore, shall be evaluated in farmers' field under Pre-production Evaluation Trial and Production Evaluation trial in coming seasons to validate the performance and preferences of farmers. The organoleptic test, grain quality test, yield stability assessment and participatory varietal selection in farmers' field would be done which would provide further selection of these entries.

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Impact of Climate Variability on Paddy Productivity in Shaba Gewog, Paro

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ABSTRACT

Rainfall fluctuations are largely random with no systematic change detectable on either annual or monthly scale. Inadequate rainfall during the growing season and heavy rainfall during harvest season reduce rice yield. This paper aimed to analyze the impacts of climate variability on paddy productivity based on questionnaire survey, data on paddy yield and meteorological data for the last 15 years,. Eighty representative households were randomly selected from a total of 265 farming households growing paddy in Shaba Gewog, Paro. Result showed that 48.8% of the farmers were aware of the climate change issues while 51.2% of farmers were not. About 25% of the respondents felt the need to shift paddy cropping calendar so that it is not affected by rain during harvest. Pearson's correlation coefficient on paddy yield and climate variability result showed that temperature (T Max) had positive correlation with paddy yield (r = .149, P = .596). The mean rainfall in October month also showed negative correlation with paddy yield (r = -.381, P = .161). The result showed that at the study site the differences in rainfall and temperature during paddy harvest season did not impact yield. About 7.5% of the respondents practiced climate change adaption techniques such as shifting of cropping calendar and change of rice variety. Reason for not adopting climate change adaptation practices was lack of awareness program in the gewog (73.8%). Majority of the farmers (97.5%) have not received any training on climate change impacts on agriculture. This study recommends capacity building programs to adopt adaptation and mitigation strategies in order to combat climate change impacts on agriculture.

Keywords: *Climate change, Impacts, Paddy yield, Rainfall, Temperature*

1. Introduction

Agriculture is the backbone of Bhutan as more than 58% of the population depends on agriculture for livelihood (Dorji, Olesen, Bocher, & Seidenkrantz, 2016). Agriculture is largely subsistence with 2.93% of the total land under cultivation. Rice and maize are the major cereal crops of Bhutan (BMCI & ICIMOD, 2016). Rice is the staple food of the Bhutanese. However, Bhutan is only 47% self sufficient in rice and as of 2018 only 28% of the total cultivable land is used for rice cultivation (GNHC, 2012). Bhutan's target for rice self-sufficiency through increase in productivity of its rice-based cropping systems in the 11 five year plan was 65- 60% (GNHC,

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2012). Bhutan has approximately 51,368 acres of wetland that produces about 86,385 MT of paddy (DoA, 2017).

Natural calamities such as rainstorms during the harvest and lack of rainfall during the transplantation season contribute to reduction in yield. There is considerable impact of the variability of rainfall and temperature on rice yield. However, studies suggest that the impact is now stronger than before (Onifade, Olagunju & Ojo, 2016). Annual rice yield and the amount of annual rainfall varied significantly from year to year and there is a significant relationship between annual rice yield and annual temperature or annual rainfall variability (Onifade, Olagunju & Ojo, 2016). According to Chophel (2017) weather and rainfall pattern have changed over the years. Bhutanese farmers experience unpredictable rainfall such as heavy rainfall during harvest season and lack of rainfall during summer.

The Intergovernmental Panel on Climate Change (IPCC) assessment report 2007, revealed that adverse impacts of climate change are expected to affect agricultural sector in Southeast Asia, including Bhutan mainly due to increase in occurrence of droughts, intense rains, and rise in temperature. Climate change will impact the productivity of both irrigated and rain fed agriculture across the globe. The occurrence of droughts is predicted to result in crop failure in areas with rain-fed cultivation, while occurrence of intense rains will result in decline in crop yield from crop damages (FAO, 2011).

Some observed signs of climate change impacts on agriculture in Bhutan include loss of crops to unusual outbreaks of pests and diseases (BMCI & ICIMOD, 2016). Heavy rainfall during the harvest season affected paddy yield. Paddy harvest in Paro valley starts from the first week of October and ends at the end of same month. Over the years, the country has experienced rapid changes in average temperatures, precipitation patterns, and increased risks of climate hazards, including excessive rains, flash floods, windstorms, hailstorms, and droughts, causing massive losses and damage to farming households (DoA, 2016).

Rice is indispensable in Bhutanese culture, tradition, religion as well as for farmers' livelihood (NBC, 2015). Climate change impacts are a reality as its consequences are already being felt. Impact of climate variability leads to reduction in rice yield due to inadequate rainfall during the growing season and heavy rainfall during harvest season. There is urgent need to focus on research works to understand and mitigate the impacts. Therefore, the main objective of the study was to assess the effect of weather variability and rainfall pattern on paddy production and productivity over the last 15 years (2003-2017), and also to analyze the level of awareness on climate change among the paddy growers.

2. Materials and Methods

2.1 Study area

The study was conducted in Shaba gewog 27°22'11.83"N and89°27'45.092" under Paro dzongkhag. It has a total cultivated area of 19,817 acres from which 522.7 acres are under wetland category.

Shaba gewog is generally warm and has temperate climate with average annual temperature of 12.4^{o}C. In winter, there is much less rainfall than in summer with average annual rainfall of 1,820mm. The study site has sandy-loam and clay- loam soil which is favorable for agricultural activities.

In 2017, the gewog produced approximately 1,402.2 MT of paddy from 492 acres with an average yield of 2.85MT per acre. From a total of 438 households in the gewog, 265 households grow paddy. It is one of the major rice producing gewogs under Paro Dzongkhag.

2.2 Sampling Method and Sample size

From the sampling frame of 265 farming households in the Gewog, 30% of the paddy growing households were selected. Therefore, 80 representative households from the Gewog were randomly selected using a simple random sampling technique. The household list of paddy growers was collected from the gewog agriculture extension supervisor.

2.3 Data Collection

Both primary and secondary data were collected. Primary data was collected through household interview using a semi-structured questionnaire. The pre-tested questionnaire comprised both close and open-ended questions. The respondents were asked questions on climate variability and its impact on paddy production amongst others. To obtain qualitative output the heads of the sampled households or household members who are fully involved in agriculture activities were interviewed.

Secondary data for climatic parameter such as rainfall and monthly maximum and minimum temperature data of the last 15 consecutive years were collected from the National Centre for Hydrology and Meteorology (NCHM), Thimphu. Agriculture statistics through publications for the last 15 successive years (2003-2017) was collected from Dzongkhag Agriculture Sector, Paro and the Department of Agriculture (DoA), Thimphu.

2.4 Data Analysis

Meteorological data of last 15 years (2003-2017) were used to compare the variation of weather variables such as precipitation, temperature and humidity over the years and to analyze the effect of variables on paddy production, in order to study the intensity of rainfall during paddy harvest season. Agriculture statistics of the last 15 years (2003-2017) were used to assess the paddy production variation over the years in relation to rainfall intensity.

The data were analyzed using Statistical Package for Social Sciences (SPSS) (version 23). Correlation analyses were conducted to see the relationship between paddy production and rainfall intensity during the harvest season. Descriptive analyses were used to assess respondents' perception on climate change impacts on paddy yield and adaptation strategies.

3. Results and Discussion

3.1 Demography

The details of the respondents such as gender, age and education backgrounds are presented in Table 1. Result showed that 70% of respondents were female and 30% male indicating more female respondents since men remained away from their home for off-farm activities during winter season. The maximum age of the respondent was 85 years old and the minimum 25 years while the mean age was 53 years old. Maximum respondents were uneducated (62.5%). Less than 12% had attended High School and college.

Table 1. Demographic details of the respondents

Gender		Education background		Age (Years old)	
	Respondents (%)		Respondents (%)		
Male	30	None	62.5	Mean	53
Female	70	NFE	10	Minimum	25
		Primary School	15	Maximum	85
		High School	7.5		
		College	3.8		
		Others	1.3		

(n=80)

3.2 Paddy variety cultivated at study site

At the time of study there were 12 varieties of paddy cultivated in five chewogs in the gewog. The most commonly cultivated variety was Yuseray Maap, locally known as "Satra", which accounts for 45% of paddy production in the gewog. More than 28.8% of the farmers at the study site cultivated Dumja followed by Thimja (6.3%). Other varieties were grown in small quantities.

The Dzongkhag Agriculture Office, Paro and neighbors were the main source of paddy seeds at 38.8% and 37.4% respectively. About 23.8% of the respondents also saved their own seeds, particularly Dumja variety.

Table 2. Paddy variety cultivated and seed source

Paddy variety cultivated	Respondents (%)	Seed source	Respondents (%)
Yuseray Maap (Satra)	45	Neighbor	37.4
Janam	2.5	Agriculture	38.8
Japanrice	5	Self saved	23.8
Dumja	28.8		
Yuseray Kaap	2.5		
Napele	1.3		
Thimja	6.3		
Jarey	1.3		
Parochina	2.5		
Upa Thungku	1.3		
Jawtshering	2.5		
Tantshering	1		

(n=80)

3.3 Cropping calendar in the study site

From early February through late March farmers prepare their land and manure the field from early March to late April. Seeds are sown in early February in the nursery. The paddy is transplanted early May. Weeding is done thrice- first weeding is done in the first week of June, second a month later and the third is also a month after the second weeding in August. Harvesting and threshing of paddy starts from the first week and ends in the third week of October (Figure 2).

Farmyard manure at the rate of 1.5 ton/ac is applied during field preparation followed by butachlor (pre-emergence herbicide) application after 2-3 days of transplanting. Suphala (46% nitrogen, 16% phosphorus, 60% potassium) and urea (46% nitrogen) is applied in July at the time of second weeding. Butachlor, suphala and urea are applied at the rate of 10 kg/ac, 20 kg/ac and 10 kg/ac, respectively. At the study site, irrigation is done on rotation basis among the farmers if there is no enough rainfall during the cropping season. Irrigation is usually done 1-2 days before weeding and during paddy flowering stage in July.

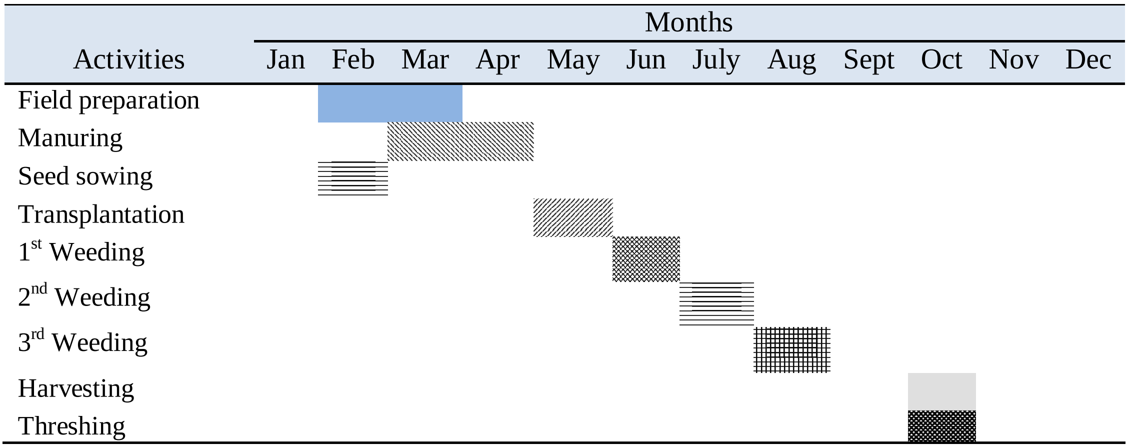

Figure 2. Cropping calendar.

3.4 Farmers' perception on climate change

From the total 80 sampled households, 48.8% of the respondents were aware of climate change issues while 51.2% were not. Those who were aware of the climate change issues stated that their source of awareness was their own experiences (40%). The media was also a source of information for 7% of the respondents (see Table 3). Therefore, the result showed the need for awareness program among the farming communities since more than 50% of the farmers were unaware of climate change issues.

SNV & DoA (2015) also reported that access to climate forecasting and advisory service for farmers is non-existent or is very poor and the availability of climate-smart technologies for adaptation is limited. Overall, preparedness and adaptive capacity for climate related risks and disasters are poor in farming communities in the country.

Table 3. Source of climate issue awareness (80)

Knowledge on climate change		Source of information	
	Respondents (%)		Respondents (%)
Yes	48.8	Media	8.8
No	51.2	Agriculture staff	0
		Gup	0
		Awareness programs	0
		Self experiences	40
		School children's	0

3.5 Perception on climatic parameters

Twenty percent of the respondents felt that rainfall (drizzling) started from February-March and 33.8% of the respondents felt that moderate rainfall (not too much, not too little rainfall) was received in June and July. Further, 22.5% of the respondent noted that heavy rainfall (greater than 100mm in 24 hours) was received from August to September. About 48.8% of the respondents reported no rain in December and January.

Table 4. Respondents (80) perception on rainfall intensity

Rainfall intensity	Month	Respondents (%)
Drizzling	Feb-March	20
Moderate rainfall (Not too much not too little)	June-July	33.8
Heavy rainfall (Grater than 100mm in 24 hours)	Aug-Sept	22.5
No rainfall	Dec-Jan	48.8

Table 5 shows that 83.3% of the respondents felt a rise in summer temperature whilst 55% felt rise in winter temperature. Twenty percent of the respondents felt winter temperature has decreased while 1.3% felt so for summer temperature. About 53.8% of the respondents felt a decline in summer rainfall while 48.8% felt decline in winter rainfall.

Table 5. Respondents' perception on climate anomalies in the last 15 years (2003-2017)

Anomalies		Temperature	Rainfall
		Respondents (%)	Respondents (%)
Summer	Increasing	83.8	12.5
	Decreasing	1.3	53.8
	Same	8.8	13.8
	Don't know	6.3	20
Winter	Increasing	55	11.3
	Decreasing	20	48.8
	Same	16.3	23.8
	Don't know	8.8	16.3

To compare the respondents' perception on climatic parameters, meteorological data of the last 15 years (2003-2017) was collected from the National Centre for Hydrology and Meteorology (NCHM), Thimphu. Due to the lack of meteorological station in the study site (Shaba Gewog), the Department provided the data collected from the National Seed Centre (Chundudingkha, Paro) which is 4 km away from the study site. The result presented in Figure 4 show that over the last 15 years, there was slight decrease in summer temperature and a gradual decline in winter temperature as well, which reached negative 0.4°C in 2017. Similar results were reported on the decline of winter mean temperatures in temperate regions (DoA, 2016). According to Shahnawaz & Strobl (2015) higher parts of the Himalayas receive a lot of snow during winter months and the cold winds blowing downward bring instant changes in the temperatures to the lower elevations. The temperatures on clear winter nights often fall to -10° C at altitudes between 2,000-3,000 masl.

Therefore, without considering micro-climatic condition of the region, farmers' perception that temperature during summer and winter are increasing does not corroborate with the data from Hydro-Met Service. Kusters & Wangdi (2013) also reported that it is difficult to identify general patterns in the region, since precipitation is highly location-specific, depending on the local topography and micro-climatic factors.

Rice grown under flooded condition in cool climates may be subjected to sub-optimal water temperature at any stage of the crop cycle. Plants in this surrounding area experience delayed heading, heads do not fill, or maturity is not reached by the end of the normal growing season, which result in decline of yield (Roel, Mutters, Eckert, & Plant, 2005).

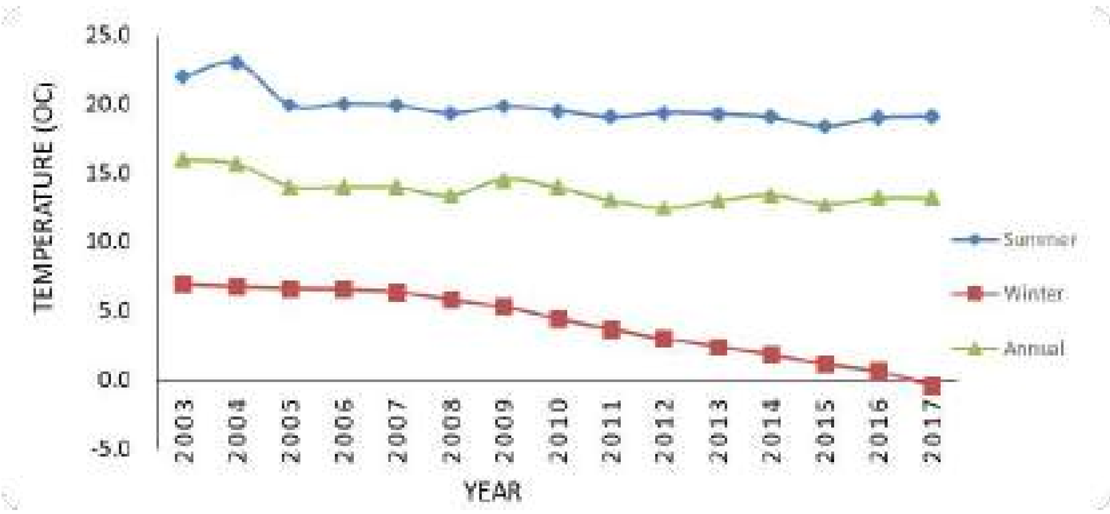

Figure 3. Average temperature of summer, winter and annual of the last 15 years

The rainfall data collected from the NCHM, Thimphu, revealed that the intensity of winter rainfall steadily increased over the last 15 years (2003-2017). There is not much variation in summer rainfall except for 2006 with exponential increase in rainfall intensity (355 mm) compared to other years.

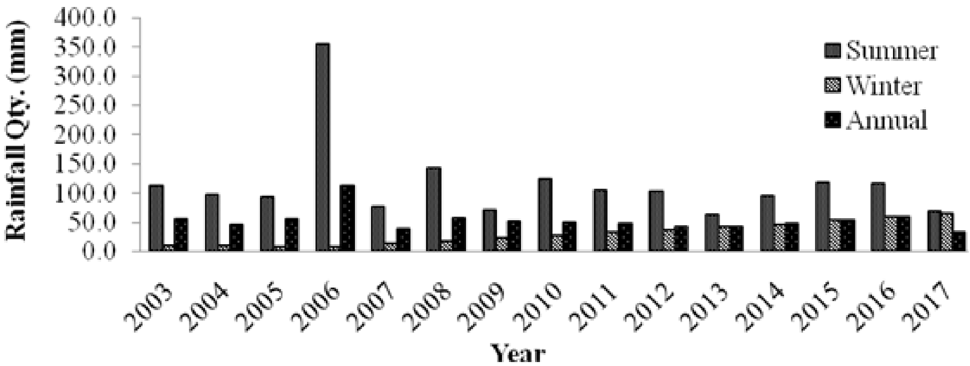

Figure 4. Average annual, summer and winter rainfall for the last 15 years

3.6 Rainfall intensity during paddy harvest and transplantation season

During paddy transplantation season, more than 60% of the respondents received enough rainfall against 37.5% who did not. Some respondents felt they received rain early by a month (2.5%) while 17.5% of the respondents felt that they received rain late by two weeks during the transplanting season.

Majority of the respondents (83.8%) believed that late monsoon rain coincided with paddy harvest. Seventy-five percent of the respondents felt that monsoon rain started in late May and ended in the second week of October (37.5%) (Table 6).

Table 6**.** Farmers' perception on rainfall timing during paddy transplantation season and harvest season in the last 15 years

Adequate rainfall during transplantation

		Early		Late	
	Respondents (%)		Respondents (%)		Respondents (%)
Yes	63	Two weeks	1.3	One week	2.5
No	38	Three weeks	1.3	Two weeks	18
		One month	2.5	Three weeks	3.8
				Four weeks	1.3
				One month	8.8

Rainfall during harvest season (October month)

		Start		End	
	Respondents (%)		Respondents (%)		Respondents (%)
Yes	84	First week	75	First week	33
No	15	Second week	7.5	Second week	38
		Fourth week	2.5	Third week	7.5
				Fourth week	7.5

Arrival of monsoon rain in the gewog was perceived to be late in the last 15 years according to 42% of the respondents. Figure 5 shows that 24% of the respondents were unsure about the timing of the monsoon rain. Generally, monsoon in Bhutan starts in early June, lasting through late September, and it usually brings significant amount of rainfall that triggers rise in water levels, flooding and landslides (NCHM, 2017).

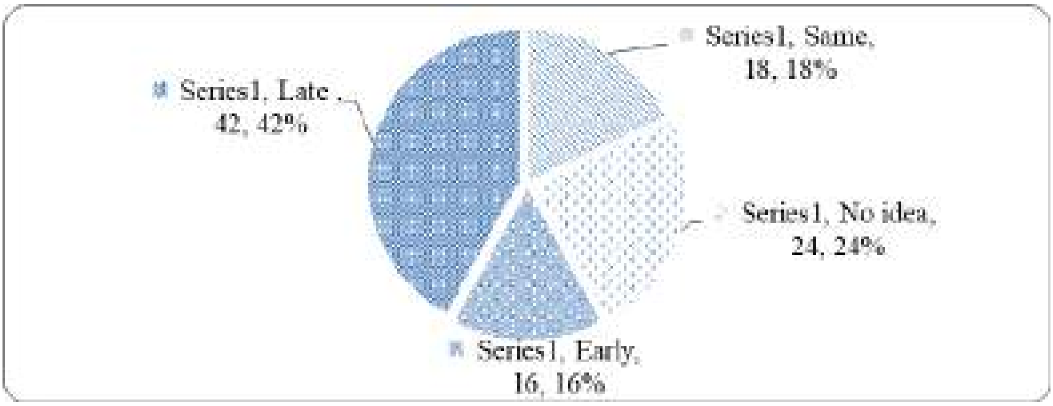

Figure 5. Respondents' perception on start of monsoon rain in the last 15 years

3.7 Paddy production variation over the last 15 years

Paddy yield has increased over the last 15 years as presented in Table 7. About 73.8% (59) of the respondents felt paddy yield increased while 26.3% (21) of them did not think so. The mean yield increased to about 1,541.1 kg/ac from 1,379.3kg/ac in 2002. At the time of this study, the maximum yield was about 2,400 kg/ac. The result is supported by agriculture statistics of the last 15 years (2003-2017). In 2003, the mean yield was 1,309 kg/ac and in 2017 the yield increased to 2,500 kg/ac.

The improvement in yield is attributed to use of improved seed varieties provided by the Dzongkhag Agriculture Sector, Paro in collaboration with the research centre in Yusipang and the National Seed Centre. Kusters & Wangdi (2013) also reported that paddy yield has been increasing because of access to improved technologies, including the use of chemical fertilizers, pesticides and improved seeds.

Table 7. Variation in paddy production for the last 15 years (2003-2017)

	%		Average Present yield (kg/ac)	Average Yield before 15 years (kg/ac)
Yes	73.8	Mean	1,541.1	1,379.3
No	26.2	Minimum	100	300
		Maximum	2,400	1,800

2.8. Climate variability impact on paddy yield

To find the relationship between climate variability and paddy yield, the average climate data of October month and paddy yield data of the last 15 years (2003- 2017) were analyzed. Pearson's correlation coefficient on paddy yield and climate variability result showed that maximum temperature (T Max) had positive correlation with paddy yield (r = .149, P = .596). There was a significant negative relationship between minimum temperature (T Min) and paddy yield (r = -.554, P = .032). Therefore, results show that grain yield decreased with increase in minimum temperature (P< .05). The mean rainfall of October month also showed negative correlation with paddy yield (r = -.381, P= .161). Results indicate that at the study site the rainfall during paddy harvest season did not impact yield.

Table 8. Relationship between paddy yield and climate variability

	T Max	T Min	Rainfall	Paddy yield
T Max	1.000	-.355	-.211	.149
Sig. (2-tailed)		.194	.449	.596
T Min		1.000	.356	-.554*
Sig. (2-tailed)			.193	.032
Rainfall			1.000	-.381
Sig. (2-tailed)				.161
Paddy yield				1.000
Sig. (2-tailed)				

* Correlation is significant at 0 .05 level (2-tailed).

3.9 Paddy loss (kg) due to natural calamities

Out of 80 respondents, only 6% experienced natural calamities such as flood, drought and hailstones impacting paddy production over the last 15 years. The study (Table 9) show that flood in 2008 and 2017 affected 3.30 acres of paddy field which resulted in a loss of 3,750 kg of paddy. In 2011 and 2018, due to less rainfall during the cropping season 1.9 ac of paddy field was affected, resulting in a loss of about 607.50 kg of paddy. In 2013 and 2014, due to hailstorm 1.3 ac of paddy field was affected that resulted in loss of about 860 kg of paddy.

The study showed (Table 9) that there was not much pest and disease outbreak associated with excessive and scanty rainfall during the cropping season. In 2013, armyworm (pest) outbreak in paddy nursery damaged around 25.2 ac. However, this did not affect production because seeds were re-sown or paddy seedlings were purchased from neighborhood within the gewog.

Table 9. Paddy quantity loss (kg) due to natural calamities

Respondents (%)		Causes	Damage area (acre)			Estimated loss (kg)		
			Min	Max	Sum	Min	Max	Sum
Yes	7.5	Flood	0.3	3	3.3	300	3,450.0	3,750.0
No	92.5	Drought	0	1	1.9	22.5	360	607.5
		Hail stone	0.3	0.6	1.3	20	600	860
		Pest outbreak due to heavy rain fall	0	0	0	0	0	0
		Disease outbreak due to heavy rain fall	0	0	0	0	0	0
		Pest outbreak due to shortage of rain fall	0	2	25.2	0	0	0
		Disease outbreak due to Shortage of rain fall	0	0	0	0	0	0
Total			0.6	6.6	31.6	342.5	4410	5217.5

3.10 Farmers' perception on cropping calendar shift

Figure 2 shows that majority of farmers (81.3%) in the study site sow paddy seeds in the first week of February and transplant the seedlings in the first week of May. Harvesting is done from the first week of October onwards. Out of 80 respondents, 25% felt the need to shift paddy cropping calendar by a week later than their earlier practice as presented in Table 10, because they felt that they receive rain a week later than the usual time. With this shift in seed sowing and transplantation time, the respondents expect to harvest their paddy crop in the second week of October month. This way paddy will not be affected by rainfall at harvest.

Seventy five percent of the respondents felt that they do not require cropping calendar shift, because weather condition is erratic anyway and therefore, they felt they will not be in a position to determine when exactly to start their work. As such they were comfortable with their usual practice. The other reason for the reluctance to shift cropping calendar was because of the traditional belief wherein wealthy farmers in the community are expected to lead the work first after performing religious rituals. Those who do not adhere to this traditional practice and who start working their fields earlier or later than the ritual ceremony, are obliged to bear all costs incurred in the event of any disaster occurring in that particular year.

Table 10. Perception on cropping calendar shifting

	Respondent (%)	Activity	Month	Respondent (%)	Week	Respondent (%)
Yes	25		Feb	22.5	1	2.5
No	75	Seed sowing	Mar	1.3	2	13.8
			Apr	1.3	3	6.3
					4	2.5
			Apr	1.3	1	6.3
		Transplantation	May	21.3	2	10
			Jun	2.5	3	6.3
					4	2.5
			Sept	1.3	2	11.3
		Harvesting	Oct	23.8	3	10
					4	3.8

3.11 Response on climate change adaptation practices

Out of 80 respondents 7.5% (6) practiced climate change adaption techniques such as shifting of cropping calendar and change of crop variety. Among three techniques such as cropping calendar shift, change of variety and rain water harvesting, 5 respondents out of 6 had adopted paddy seed replacement technique since 2012. Farmers observed that the increase in paddy yield was due to adoption of new seed variety (Yuseray Maap) in place of their local seed.

The reason for not adopting climate change adaptation practice was lack of awareness program in the gewog (73.8%). About 10% of the respondents had no idea of such techniques (Table 11). Many adaptation strategies for the agricultural sector are constrained by a lack of information on regionally specific climate change impacts on key crops (Chogyel & Kumar, 2018; Parker et al., 2017).

Table 11. Response on climate change adaptation practices

Respondent (%)		Adaptation techniques	Respondent (%)	Year of adoption	Reasons of not practicing	Respondent (%)
Yes	7.5	Cropping calendar shift	1	2014	Not interested	1.2
No	93				Expensive	1.3
					No support	6.2
		Change of variety	1.1	2012	Not aware	73.8
			1.1	2013	No idea	10
			1.2	2016		
			3.1	2018		
		Rain water harvesting	0	Nil		

3.12 Constraints on climate change adaptation practice

Out of 80 households interviewed 97.5% (78) of the respondents have not received any training on impact of climate change on agriculture (Table 12). About half (48.8%) of the respondents mentioned that they are ready to participate in any forms of climate change adaptation trainings and awareness programs. Many (32.4%) of the respondents felt that training on weather forecasting would help them. The farmers also suggested the need for information on weather forecasting for at least 10 days or more before planning field work.

Remaining 15% of the respondents felt that training on cropping calendar shift and awareness or training on cultivation of right crop at right time to combat crop loss to erratic weather conditions are also equally important for building climate resilience. According to Kusters & Wangdi (2013) adaptation practices can be enhanced through better understanding of farmers' constraints on adaptation strategies. This will also help policymakers to develop strategic interventions to minimize crop loss and damages. There is also a need to enhance resilience of farming community on the impacts of climate change through enhanced cross-sectoral strategic options such as enhanced investment, technology generation, and research and development (Chhogyel & Kumar, 2018).

Table 12. Proposed training/awareness to farming community

	Respondents (%)	Categories of training/awareness programs	Respondents (%)
Yes	2.5	Need on cropping calendar change	10
No	97.5	Timing on different crop cultivation season	5
		Weather forecasting	32.4
		Adaptation practices	3.8
		Any climate related trainings	48.8

5. Conclusion

Rice is a staple food crop of the Bhutanese people. The impact of climate change on rice productivity is of particular interest due to its importance as a major food source of the country. Bhutan is already under pressure from climate stresses which increase vulnerability to further climate change impacts and reduce adaptive capacity. The resilience of paddy production systems to changes in climate can be enhanced by improved understanding of impacts and responses of crops to changing climate.

Adverse impacts of climate change are expected to affect agriculture sector in Southeast Asia including Bhutan mainly due to increase in occurrence of droughts, intense rains, and rise in temperature. Natural calamities such as rainstorms during the harvest season and lack of rainfall during the transplantation season contribute to reduction in crop yield. There is considerable impact of the variability of rainfall and temperature on rice yield.

The major adaptation practice to climate change found in rice farming was the selection of new rice varieties for higher resilience. The major climatic factor affecting rice production in the study area is temperature (T Min). The mean rainfall in October also shows negative correlation with paddy yield. In the last 15 years (2003-2017), natural calamities such as flood, inadequate rainfall during paddy cropping season and hailstorms resulted in substantial loss of paddy. Therefore, under changing climatic conditions it is necessary to introduce crops which can withstand fluctuating temperature and other natural factors.

It is observed that climate change adaptation practices adopted by farmers are limited. This study reveals the cause for not adopting climate change adaptation practice as lack of awareness programs. Therefore, there is an urgent need for awareness and advocacy programs for the farming communities on climate change issues.

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Identification of Suitable Sowing Time for Quinoa (*Chenopodium quinoa* Willd.) at Samtenling

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ABSTRACT

Trials on different sowing dates were conducted at the Agriculture Research and Development Centre, Samtenling to determine suitable planting time for quinoa. Four quinoa varieties: Ivory 123, DoA-1-PMB 2015, Amarilla Sacaca and Amarilla Marangani were sown at six different planting dates starting from 17 September to 6 December 2018. The exact sowing dates were 17 September, 2 October, 17 October, 6 November, 16 November and 6 December. Each sowing date was staggered at an interval of 15 days. The effects of sowing time on grain yield and other agronomic traits were analyzed. No data were obtained from first sowing and sixth sowing (17 September and 6 December 2018) due to poor seed germination. The results indicated that mid October to mid-November is the most suitable sowing time for quinoa in Samtenling which represents the humid-subtropical agro-ecological zone. Comparative analyses between the four varieties indicate that Ivory 123 and DoA-1-PMB could be preferably sown in mid-October. Mid-November is a preferred sowing time for Amarilla Sacaca and Amarilla Marangani since significantly greater yields (2.49 t/ha and 2.56 t/ha respectively) were obtained as compared to seeds sown in October. Although there were no significant differences in grain yields both Ivory 123 and DoA-1-PMB 2015 took significantly shorter durations (82.8 days and 84.6 days respectively) to mature and produced significantly shorter plant heights (75.5cm and 93.6 cm respectively) when seeds were sown in mid-October. Amarilla Sacaca and Amarilla Marangani took longer durations to mature (110.6-132 days) and produced significantly longer plant heights (135.6cm and 145.2 cm respectively) when seeds were sown in mid-November as compared to seeds sown in October. Based on the result of a one-year trial, it can be concluded that all the four released quinoa varieties can be sown from mid-October to mid-November in Samtenling which represents the humid agro-ecological zone.

Keywords: *Sowing time, Humid-subtropical agro-ecological zone, Quinoa varieties, Maturity, Yield*

1. Introduction

Quinoa (*Chenopodium quinoa* Willd.) is a potential, new and a future crop that could play a pivotal role in food security. Quinoa has been reported to have made an important contribution to the staple needs of the population of the Andean countries (Rojas, 2015). The General Assembly of the United Nations declared 2013 as the International Year of Quinoa, highlighting the potential

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potential role of quinoa in contributing to global food security, given its high nutritional value and tremendous potential to adapt to different agro-climatic conditions (Bazile, D., Chevarria-Lazo, M., Dessauw, D., Louafi, S., Trommetter, M., & Hocdé, H. (2015). The nutritional qualities of quinoa and its suitability for use by people with celiac disease, has resulted in an increased worldwide demand of quinoa-based food products (Casini, 2018).

Quinoa was firstly introduced to Bhutan from Peru in 2015 by the Department of Agriculture (DoA) with the support of the FAO (Katwal, 2018). It is known for its ability to grow in extreme temperatures ranging from -4 ^{0}C to 38 ^{0}C and at relative humidity ranging from 40% to 88% (FAO, 2011), and tolerate adverse abiotic stresses such as drought and saline conditions. Moreover, its efficient use of water makes quinoa an excellent alternative crop in the face of climate change (FAO, 2011).

The main objectives of introducing this new crop to Bhutan are to diversify existing cropping systems, adapt this versatile crop to different growing environments as a climate resilient crop, and to enhance the food and nutritional security of the Bhutanese people (Katwal, Wangdi, & Giri, 2019). Since its introduction evaluations were carried out from 2015-2016 by the National Quinoa Commodity Program to assess its adaptability. Thereafter, general information on quinoa and its package of practices was generated based on the results of the first two years of adaptive evaluations carried out at six different locations across the country. More importantly, the 20th Variety Release Committee (VRC) of the Ministry of Agriculture and Forests (MoAF) released four varieties for cultivation under different cropping systems and agro-ecology (Table 1). Furthermore, to popularize the newly introduced crop among the farmers, the Department of Agriculture also gave local Bhutanese names for Quinoa (Table 1) (Katwal et al., 2019).

Table 1. Information on four released varieties (with local names)

Bhutanese name	Original name	Origin	Plant height (cm)	Maturity (days)	Grain colour	Mean yield (t/ha)
AshiHeychum-AM	Amarilla Marangani	Peru	188	173	Yellow	1.88
AshiHeychum-AS	Amarilla Sacaca	Peru	165	170	Yellow	2.25
Ashi Heychum-123	Ivory 123	India	122	150	Brownish	2.25
AshiHeychum-TW	DoA-1-PMB-2015	Unknown	120	140	Brownish	1.88

Source: Katwal, 2019

Quinoa grows well under a wide range of soil and climate conditions, from cold and arid areas to wet tropical regions. The adaptability of quinoa to various levels of drought is due to the differentiation of a diversity of ecotypes originating in contrasting agro-environments (Silva, 2013). Considering the conditions where quinoa is cultivated and the genetic variability available, quinoa has a remarkable adaptability to different agro-ecological zones. It adapts to different climates and the crop can grow at relative humidity from 40% to 88%. Temperatures between 15 to 20 ° C are ideal for cultivation and can withstand temperatures from -4 ° C to 38 ° C. A water efficient plant, it is tolerant and resistant to lack of soil moisture, obtaining acceptable yields with rainfall of 100 to 200 mm (FAO, 2011)**.** The general climate of Samtenling is humid subtropical which consists of hot and humid summer with monthly mean temperatures of 24^{0}C to 29^{0}C, average rainfall of 312.6 mm and average relative humidity of 90.29%. It exhibits cold to mild winters with average monthly temperatures of 14^{0}Cto 23^{0}C with negligible mean rainfall of 2.5 mm. Mild temperatures and light rainfall are observed in Autumn months (September to November) with average temperatures of 21^{0}C to 27^{0}C and mean rainfall of 133 mm. Similar conditions are observed in spring season (March to May) although much less average rainfall of 61.5 mm is observed (NCHM, 2018).

According to Casini (2019), the identification of the most suitable sowing date is critical for the successful cultivation of quinoa. Although initial on-station observation trials and on-farm demonstrations on quinoa cultivation were carried out by Agriculture Research and Development Centre (ARDC), Samtenling from 2016 to 2017 no data were obtained due to poor seed germination which could have been due to high temperature during the sowing time. Also, the coincidence of heavy rainfall during seedling stage contributed to its failure which was mainly due to the lack of adequate knowledge on its suitable sowing period particularly for Samtenling agro-climatic condition. Later, the results of adaptive trials conducted by the National Commodity Quinoa Program from 2015-2016 as well as repeated failures and experiences gained on quinoa cultivation hinted at the possibility of cultivating quinoa at ARDC Samtenling by adjusting the sowing time within September to December under Samtenling agro-ecological condition. In the lower elevations (<1200 masl) when quinoa was sown in the maize-based dry lands in March, the vegetative growth and flowering were good but there was no grain setting. However, sowing within October to January gave good yield with hastened crop maturity due to low rainfall during winter months and higher temperature at the sites (Katwal et al., 2019).

The aim of this trial was to identify the most suitable sowing period for quinoa under the humid sub-tropical agro ecological zone and to assess the suitability of cultivating quinoa crop in the humid sub-tropical agro-ecology.

2. Materials and Methods

2.1. Experimental site

The experiment was conducted at Agriculture Research and Development Centre (ARDC), Samtenling Gewog, Sarpang Dzongkhag which is located at 375 meters above sea level.

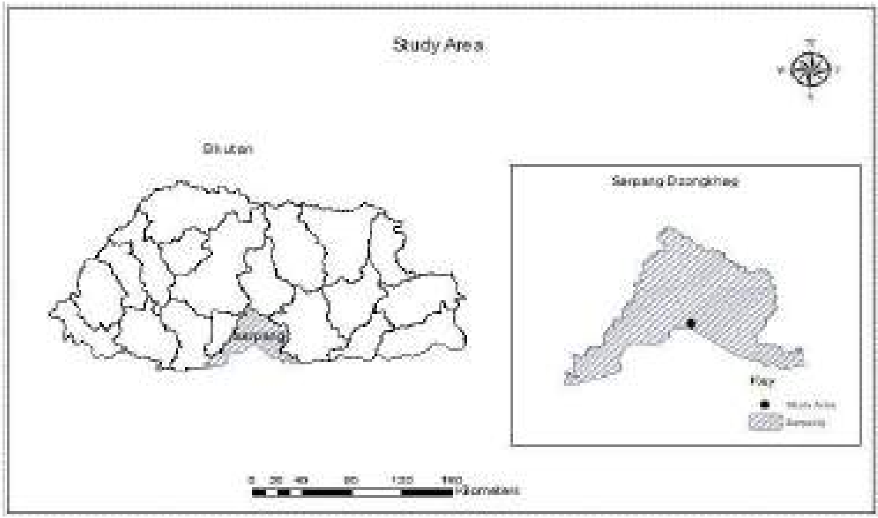


Figure 1. Map of Bhutan showing the experimental site (ARDC Samtenling) in Sarpang

ARDC Samtenling falls under humid subtropical zone which consists of hot and humid summer and cold to mild winters with annual mean temperatures of 200C to 270C and annual average rainfall of 123 mm.The relative humidity ranges from 70% in winter to as high as 90% in summer. Maximum rainfall of up to 360 mm is observed in summer while as low as 0 mm of rainfall is observed in winter. A total rainfall of 400 mm is observed in autumn with average temperatures ranging from 210C to 270C while much lower rainfall of 185 mm with similar mean temperatures are observed in spring season (NCHM, 2018).

2.2. Experimental design

The experiment was laid out in a split-plot design consisting of main plots as well as sub-plots. Six different planting dates were the main-plot factors while the four quinoa varieties were sub-plot factors. In each main plot the sub-plots consisting of four quinoa varieties were laid out in a randomized complete block design with five replications. Each plot size measured 3m x 2m ($6m^2$). Hence, each main plot had 20 sub-plots making a total of 120 plots (experimental units).

2.3. Treatments and methodology

The seeds of four quinoa varieties were sown on six different sowing dates which were the treatments of this experiment (Table 2). Seeds were sown in line maintaining row to row spacing of 60cm and thinning was carried out after 21 days of sowing to maintain a plant to plant spacing of 10-15cm. A total of 0.12 MT of FYM was applied in the experimental plot to enrich the soil with adequate nitrogen for enhanced growth and development of plants. Three times of manual weeding was carried out to avoid stress due to crop-weed competition.

Table 2. Details of the treatments of the experiment

Treatments (T)	Time of sowing	Treatments (V) (main-plot)	Varieties (sub-plot)
T1	17 September	V1	Ashi Heychum-123
T2	2 October	V2	Ashi Heychum-TW
T3	17 October	V3	Ashi Heychum-AM
T4	6 November	V4	Ashi Heychum-AS
T5	16 November		
T6	6 December		

2.4. Data collection

The data on grain yield, plant height, 1000 grain weight and days to maturity were collected to analyze and compare the effects of sowing time on the performance of the four varieties. Treatments T_1 (1^{st} sowing) and T_6 (6^{th} sowing) were excluded from the experiment as there was no germination in the experimental plots. The data on plant height was recorded one week prior to harvesting while maturity days were calculated from the day of sowing until physiological maturity of the grains. The grain yield per plot was recorded in kilograms after harvesting three middle rows consisting a section of $3.6m^2$ with 60 plants. A section of 2.4 m^2 consisting of two outer rows were discarded to avoid border effect. The harvested plant samples were dried for a week before threshing and weighing using electrical weighing balance. The grain samples were adequately dried in the sunlight to maintain grain moisture content below 10%. 1000 grain weights of each treatment were recorded by weighing three sets of 1000 grain samples using electrical weighing balance which had a calibration in gram unit. The average of 1000 grain weights of three sample sets were taken for data analysis.

2.5. Data analysis

Data collected were analyzed using MS Excel and STAR (Statistical Tool for Agricultural Research) version 2.0.1.

3. Results and Discussion

Results from this trial indicate that quinoa can be successfully cultivated in the humid sub-tropical agro-ecology, represented here by Samtenling, when sown after the second fortnight of October to second fortnight of November.

3.1 Effect of sowing time on maturity days

Upon analysis significant difference was observed in the maturity days of each quinoa variety sown on different dates as given in Table 3. All the four varieties took significantly shorter maturity durations ranging between 82.8 - 110.4 days when seeds were sown on 2 October, 17 October and 6 November as compared to their maturity days resulted from sowing on 6 November which ranged from 116.8 -132.4 days. Seeds of Ashi Heychum-123, Ashi Heychum-TW and Ashi Heychum-AS sown in October matured significantly earlier than seeds sown in November (Table 3). No significant difference was observed in crop maturity duration of Ashi Heychum-AM from the second sowing (2 October) until the fourth sowing (6 November).

Table 3. Effect of sowing time on maturity days of each variety

Treatments (TOS*)	Ashi Heychum -123	Ashi Heychum -TW	Ashi Heychum - AS	Ashi Heychum - AM
02/10/2018	85.8^{c}	83.0^{c}	97.4 ^{c}	106.4^{b}
17/10/2018	84.6^{c}	82.8^{c}	101.8^{c}	107.0^{b}
06/11/2018	92.2^{b}	88.8^{b}	110.6^{b}	110.6^{b}
16/11/2018	116.8^{a}	118.2^{a}	123.0^{a}`	132.4^{a}
P value	**	**	**	**
C.V. (%)	3.72	3.72	3.72	3.72

***P*< (0.05); Means with the same letters are not significantly different, *TOS= Time of sowing

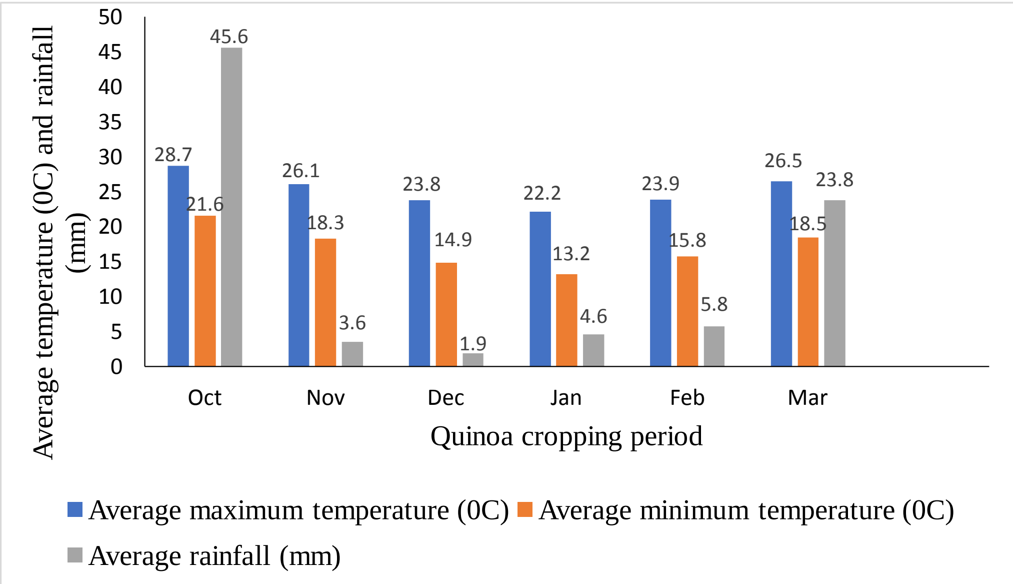
A comparative analysis of varieties at each level of time of sowing (Table 4) indicated that Ashi Heychum-123 and Ashi Heychum-TW matured significantly earlier (82.8-118.2 days) than Ashi Heychum-AS and Ashi Heychum-AM irrespective of sowing time. Katwal (2018) also reported that Ashi Heychum-TW and Ashi Heychum-123 took significantly shorter durations of 120 to 150 days to mature while the other two varieties took 170 to 180 days at high altitude areas above 1200 masl. Therefore, it indicates that the two varieties are inherently early maturing varieties while Ashi Heychum-AS and Ashi Heychum-AM are late maturing varieties.'

Table 4. Comparison of maturity days between varieties at each sowing time

Treatments	Treatments (Time of sowing)			
	02/10/2018	17/10/2018	06/11/2018	16/11/2018
Ashi Heychum-123	85.8^{c}	84.6^{c}	92.2^{b}	116.8^{c}
Ashi Heychum-TW	83.0^{c}	82.8^{c}	88.8^{b}	118.2^{bc}
Ashi Heychum-AS	97.4^{b}	101.8^{b}	110.6^{a}	123.0^{b}
Ashi Heychum-AM	106.4^{a}	107.0^{a}	110.6^{a}	132.4^{a}
P value	**	**	**	**
C.V. (%)	3.72	3.72	3.72	3.72

***P*<(0.5); Means with the same letters are not significantly different

Crop maturity duration of plants is one of the key determining factors of the adaptation of a species (Bertero, 2015). Since, temperature is the environmental factor with the highest relative impact on crop maturity duration (Bertero, 2015) the significant difference observed in the maturity days could be due to considerable differences in the average daily temperature between the cropping periods. The temperature data obtained from National Centre for Hydrology and Meteorology (NCHM) shows a gradual decrease in the average daily temperature with successive delay in sowing time from October to November 2018 (Fig 2). With the decrease in temperature there was delay in physiological maturity of each quinoa variety resulting in significant differences in crop maturity duration of all the four varieties.



Source: NCHM (2018)

Fig 2. Monthly average temperature and rainfall during the cropping period

3.2 Effect of planting time on plant growth

Significant difference was observed in plant heights of different quinoa varieties sown on four different dates. In all the four varieties, shorter plant heights (75.6-99.0 cm) were observed when plants were sown on 17 October while all except Ashi Heychum-TW resulted in a significantly longer plant heights ranging from 127.8-145.2 cm when seeds were sown on 16 November (Table 4).

Table 4. Effect of sowing time on plant heights (cm) of each quinoa variety

Treatments (TOS*)	Ashi Heychum-123	Ashi Heychum-TW	Ashi Heychum-AS	Ashi Heychum-AM
02/10/2018	97.4^{bc}	93.2^{b}	113.4^{b}	114.8^{b}
17/10/2018	94.0^{c}	75.6^{c}	91.6^{c}	99.0^{c}
06/11/2018	111.8^{b}	113.2^{a}	103.8^{bc}	99.6^{c}
16/11/2018	127.8^{a}	107.4^{ab}	135.6^{a}	145.2^{a}
P value	**	**	**	**
C.V. (%)	14.43	14.43	14.43	14.43

***P*<(0.5); Means with the same letters are not significantly different, *TOS= Time of sowing

Comparison between the varieties indicated that Ashi Heychum-TW and Ashi Heychum-123 had significantly shorter plants than Ashi Heychum-AS and Ashi Heychum-AM when seeds were sown on 2 October (Table 5). Katwal (2018) also reported that Ashi Heychum-TW and Ashi Heychum-123 had shorter plant heights of 120 cm to 122 cm as compared to Ashi Heychum-AM and Ashi Heychum-AS which had significantly taller plant heights of 173 cm to 170 cm. No significant differences were observed in plant heights among the varieties except Ashi Heychum-TW which had significantly shorter plants (75.6 cm) than the rest of the varieties when plants were sown on 17 October. Ashi Heychum-AM had significantly taller plants as compared to Ashi Heychum-123 and Ashi Heychum-TW when the plants were sown on 16 November 2018.

Table 5. Comparison of plant heights (cm) between varieties at each sowing time

Treatments (Varieties)	Treatments (Time of sowing)			
	02/10/2018	17/10/2018	06/11/2018	16/11/2018
Ashi Heychum-123	97.4^{b}	94.0^{a}	111.8^{a}	127.8^{b}
Ashi Heychum-TW	93.2^{b}	75.6^{b}	113.2^{a}	107.4^{c}
Ashi Heychum-AS	113.4^{a}	91.6^{a}	103.8^{ab}	135.6^{ab}
Ashi Heychum-AM	114.8^{a}	99.0^{a}	99.6^{b}	145.2^{a}
P value	**	**	**	**
C.V. (%)	9.22	9.22	9.22	9.22

**P<(0.5); Means with the same letters are not significantly different

Although no data were recorded on lodging percentage of quinoa plants observations from on-station trials and on-farm demonstrations from 2017-18 indicated association of stem lodging incidence with longer plants than the shorter plants. As significantly shorter plant heights were observed in all the varieties when seeds were sown on 17 October, sowing of quinoa in mid-October could preferably reduce incidence of lodging in quinoa in the sub-tropical humid agro-ecological zone.

3.3 Effect of planting time on grain yield (t/ha)

Time of sowing had significant (P<0.05) effect on grain yield of each quinoa variety (Table 6). Ashi Heychum-123 produced significantly lesser grain yield (0.79 t ha^{-1}) when seeds were sown on 2 October as compared to its grain yields from seeds sown on rest of the sowing periods.

Ashi Heychum-TW produced a significantly greater grain yield (1.51 t ha^{-1}) when seeds were sown on 6 November as compared to its yield result from sowing on 2 and 17 October. Both Ashi Heychum-AS and Ashi Heychum-AM produced significantly higher grain yield (2.50 t ha^{-1} and 2.58 t ha^{-1}) when the varieties were sown on 16 November in comparison to the yield results from other sowing dates.

In general, there was increase in grain yield with successive delay in sowing time. This correlates with the gradual decreasing trend in temperature from October to November (Fig 2).

Hightemperatures during flowering and seed set can significantly reduce yield and is one of the major barriers to the global expansion of quinoa (Murphy, Hinojosa, & Matanguihan, 2018). The yield response of Ashi Heychum-AM and Ashi Heychum-AS was significantly higher in plots sown on 16th November which could be attributed to lower temperatures during the growing period. The grain yields of the two varieties are comparable to the results of the adaptation trial in low altitude areas conducted in 2016 which recorded mean yields ranging from 1.52 t ha-1 to 2.63 t ha-1(Katwal et al., 2019).

Table 6. Effect of sowing time on grain yield (t/ha) on each variety

Treatments (TOS*)	Ashi Heychum-123	Ashi Heychum-TW	Ashi Heychum-AS	Ashi Heychum-AM
02/10/2018	0.79[b]	0.54[b]	0.59[b]	0.64[c]
17/10/2018	1.61[a]	0.84[b]	1.10[b]	1.50[b]
06/11/2018	1.98[a]	1.51[a]	0.81[b]	0.86[bc]
16/11/2018	2.10[a]	0.93[ab]	2.50[a]	2.58[a]
P value	**	**	**	**
C.V. (%)	49.15	49.15	49.15	49.15

***P*< (0.5); Means with the same letters are not significantly different, *TOS= Time of sowing

The comparative analysis between the varieties on grain yield also showed significant yield differences (Table 7). The yield responses to different sowing time differed significantly between the varieties. There were no significant differences in grain yield among the varieties when seeds were sown on 2 October. However, yield response of Ashi Heychum-TW was significantly lower (0.84 t ha^{-1}) as compared to Ashi Heychum-123 (1.61 t ha$^{-1)}$ and Ashi Heychum-AM (1.50 t ha^{-1}) when seeds were sown on 17 October.

Both Ashi Heychum-123 and Ashi Heychum-TW gave significantly higher grain yields of 1.98 t ha^{-1} and 1.51 t ha^{-1} respectively as compared to Ashi Heychum-AM and Ashi Heychum-AS when seeds were sown on 6 November. Sowing on 16 November resulted in a significantly lesser grain yield (0.93 t ha^{-1}) for Ashi Heychum-TW as compared to the rest of the varieties.

Interestingly, when seeds were sown on 6 November grain yields indicated similar genetic traits between the varieties. Ashi Heychum-123 and Ashi Heychum-TW gave more or less equal grain yields of 1.98 t ha^{-1} and 1.51 t ha^{-1} respectively while Ashi Heychum-AS and Ashi Heychum-AM produced statistically equal grain yields of 0.81 t ha^{-1} and 0.86 t ha^{-1} respectively when seeds were sown on 6 November (Table 7). This agrees with the findings of Katwal (2019), who pointed out that the mean yield recorded for Ashi Heychum-AM and Ashi Heychum-AS did not show huge difference since both the varieties come from a close pedigree.

Table 7. Comparison of grain yields (t/ha) between varieties at each sowing time

Treatments (Varieties)	Treatments (Time of sowing)			
	02/10/2018	17/10/2018	06/11/2018	16/11/2018
Ashi Heychum-123	0.79^{a}	1.61^{a}	1.98^{a}	2.10^{a}
Ashi Heychum-TW	0.54^{a}	0.84^{b}	1.51^{a}	0.93^{b}
Ashi Heychum-AS	0.59^{a}	1.10^{ab}	0.81^{b}	2.50^{a}
Ashi Heychum-AM	0.64^{a}	1.50^{a}	0.86^{b}	2.58^{a}
P value	ns	**	**	**
C.V. (%)	34.56	34.56	34.56	34.56

***P*<(0.5); Means with the same letters are not significantly different

Based on the yield results Ashi Heychum-123 could be more suitably sown from mid-October to mid-November while Ashi Heychum-TW could be sown within the first week of November. Ashi Heychum-AS and Ashi Heychum-AM could be most preferably sown in mid-November as the yield response of the two varieties were significantly greater (2.50 t ha^{-1} to 2.58 t ha^{-1}) than those observed from rest of the sowing dates.

3.4 Effect of planting time on 1000 grain weight **(g)**

There was a significant difference in 1000 grain weights of varieties as a result of different sowing dates (Table 8). In Ashi Heychum-123 and Ashi Heychum-TW sowing on 6 and 16 November resulted in a significantly greater test weights ranging from 1.70g to 2.40g. This agrees with the findings of Bertero, King, & Hall (1999) in which it was reported that the maximum grain growth was obtained under short day and cool temperature. In Ashi Heychum-AS greater test weights were observed when seeds were sown from 17 October to 16 November. However, there was no significant effect of sowing time on 1000 grain weights of Ashi Heychum-AM.

Table 8. Effect of sowing time on test weights (g) of each variety

Treatments (TOS*)	Ashi Heychum 123	Ashi Heychum-TW	Ashi Heychum-AS	Ashi Heychum-AM
02/10/2018	0.30^{c}	0.97^{b}	0.96^{b}	1.78^{a}
17/10/2018	0.18^{c}	0.23^{c}	1.73^{a}	1.50^{a}
06/11/2018	1.70^{b}	2.40^{a}	1.54^{a}	1.46^{a}
16/11/2018	2.28^{a}	2.02^{a}	1.72^{a}	1.62^{a}
P value	**	**	**	**
C.V. (%)	32.30	32.30	32.30	32.30

***P*<(0.5); Means with the same letters are not significantly different, *TOS= Time of sowing

4. Conclusion

Results from one year experiment using four planting dates and four varieties indicate that quinoa crop can be successfully grown at Samtenling that represents the humid sub-tropical agro-ecological zone. The analysis of the effects of different planting time on grain yield, crop maturity, plant height and test weight showed significant differences. Based on the results of a one-year experiment, it may be concluded that mid-October to mid-November is a suitable sowing time for Samtenling agro-ecological condition for all the four varieties. Higher grain yields (0.81 t ha^{-1} to 2.58 t ha^{-1}) were obtained when seeds were sown from 17 October to 16 November 2018 as compared to the average grain yields from sowing on 2 October 2018. Interestingly, the two varieties Ashi Heychum-AS and Ashi Heychum-AM gave significantly higher yields (2.50 t ha^{-1} and 2.58 t ha^{-1} respectively) accompanied by taller plant heights (135.6 cm and 145.2 cm respectively) and took significantly longer duration to mature (123 days and 132.4 days respectively) when seeds were sown on 16 November. These characteristics correlate with the information on the four varieties provided by Katwal (2019).

Among the varieties Ashi Heychum-AM gave the highest average grain yield (2.58 t ha^{-1}) while Ashi Heychum-TW gave the lowest average grain yield (0.54 t ha^{-1}). Ashi Heychum-123 took the shortest duration to mature (82.8 days) while the longest maturity duration was observed in Ashi Heychum-AM (132.4 days).

Since quinoa is sensitive to day length and is classified as short-day plant it requires relatively cool temperatures for optimum growth. With cool temperatures and lower rainfall in October-November and shorter photoperiods, quinoa can be successfully grown in humid-subtropical agro-ecological zones if factors such as crop management and proper irrigations are also ideal. For definitive conclusions on planting time similar experiments need to be repeated within the humid-subtropical region in the country.

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Assessment of Storage Losses of Maize in Three Districts of Bhutan

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ABSTRACT

Storage loss of maize (Zea mays) in Bhutan is assumed to be high but there is insufficient data to validate it. This study was conducted in the three major maize growing districts of Bhutan covering nine locations to assess and determine the storage losses of maize in traditional method of storage in the attic floors and hanging method. The total grain loss was estimated as the sum of the percentage of grains damaged by insects and fungal diseases counted from two different storage methods and at different storage months which is estimated to be six months of storage period. At the end of six months storage, the total mean storage losses were 16.18%, 38.21% and 23.83% for Chukha, Dagana and Mongar, respectively. The damage from insect during storage was recorded at 9.11%, 36.41% and 9.81% during December while in March it increased to 14.91%, 21.99% and 15.7% for Chukha, Dagana and Mongar, respectively. Similarly, fungal damage increased from 0.95%, 8.10% and 6.50% in December to 1.27%, 16.22% and 8.03% in March for Chukha, Dagana and Mongar. There was no significant difference in losses from insect, fungal damages and total storage losses between the two storage methods. Storage losses of maize grains from insect infestation were higher compared to fungal diseases in all the study locations. Storage losses were slightly higher in the low altitude locations in all the three districts. The survey findings indicated that there is a major loss of maize during the storage with maximum losses caused by insect damage followed by fungal infection. This study recommends the design and promotion of improved storage methods and interventions in good post-harvest management to minimize losses during the storage.

Keywords: *Maize, Storage loss, Insect, Fungal*

1. Introduction

Maize (*Zea mays*) is the staple food of many Bhutanese especially in the six eastern and southern Dzongkhags of Bhutan. Maize cultivation constituted 46.3% of total cultivated area for cereals and maize constituted 45% of cereal production (MoAF, 2015). Mongar, Tashigang, Dagana, Samdrup Jongkhar, Sarpang, Pemagatshel, Tsirang and Zhemgang are major maize producing Dzongkhags in Bhutan (MoAF, 2015). It is also cultivated in small quantities in other Dzongkhags of Bhutan for self-consumption and as a cash crop in recent years.

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In the year 2017, total maize production was recorded at 94,051 MT from 66,043 acres of land with the highest production in the Dzongkags of Tashigang, Mongar, Samdrup Jongkhar, Samtse, Tsirang, Dagana and Pema Gatshel (NSB, 2018). Mongar and Tashigang recorded the highest production of 15,871 MT and 15,559 MT, respectively. With improved technologies in farming, the production of maize is increasing but the post-harvest management and technologies are still poor in the country. This leads to a high quantity of maize loss in the post-harvest stages particularly during storage. As per the findings from the farm survey on maize impact study by Shrestra, Katwal and Ghalley (2006), the overall post –harvest loss in maize was reported to be 20%. Additionally, the post-harvest loss was 26% higher among the farmers growing traditional varieties compared to those who adopted modern varieties. This annual post harvest loss in monetary terms was valued at Nu.181 million at a price of Nu.10/kg. In an unpublished report by National Post Harvest Center (2015), the damages from insects, fungal and birds were studied in Tashigang, Tashi Yangtse, Lhuntse and Samdrup Jongkhar districts and reported to be 7.6% at the beginning of the storage.

Globally, Food and Agriculture Organization (FAO) of the United Nations predicts that 1.5 billion tons of food are wasted or lost per year (FAO, 2019a). The food losses and waste amounts to roughly US$680 billion in industrialized nations and US$310 billion in developing countries. In another data from FAO and World Bank it was revealed that post harvest loss of cereal in Sub Saharan Africa ranged between 5-40 % with an estimated value of around $4 billion (FAO, 2019 b). Losses of cereal crops such as maize in the developing countries are estimated to be as high as 25% of the total production. Losses of 50-60% of cereal grain occur during the storage period due to lack of proper storage management and structures (Kumar & Kalita, 2017). It was reported by Meronuck (cited in Suleiman & Kurt, 2015) that losses of maize in various storage facilities in undeveloped tropical countries are in the range of 15-25%. In a survey study carried out in Nepal, 62% of the respondents expressed insects as the major cause of maize loss in storage and 39% of the respondents presumed storage losses to be between 10-20% (Bhandari et al., (2015).

In Bhutan, traditional method is still practiced for storage of maize. In traditional practice, maize is usually stored by piling in the attics or in small rooms attached to the house while some others keep the cobs hanging from ceilings of their houses. The traditional methods of storing de-husked maize in these methods were also described in a socio-economic impact assessment of maize commodity (DoA & PPD, 2018). These kinds of storage lead to favorable conditions for growth of fungal infections and storage pests thus incurring significant losses during storage. According to Basappa et al. (2005), the important factors leading to storage losses are long duration storage using traditional method, inadequate knowledge, poor storage structures, non-availability of separate godowns and damage by rodents, insects and dampness. Kiaya (2014) described poor storage conditions in general as one of the major factors contributing to post harvest losses of grains.

With conventional practice of maize storage and conditions favoring the growth of fungal pathogens and insects, it is presumed that the storage loss of maize in Bhutan is quite high. However, the country does not have enough data to validate the storage losses in numbers. Therefore it is important to assess the total storage losses of maize through traditional storage practices in Bhutan.

This study assessed the storage losses in the two traditional storage methods commonly practiced by farmers in Bhutan. It was conducted with an objective to obtain the baseline data on the quantity of storage losses of maize in Bhutan under traditional storage methods. The survey also aimed to specifically assess the amount of grain loss due to damage by insects and fungal infections during the storage months. The data and findings from the study will provide useful information on the amount of maize loss during storage period that can be used for future interventions and remedial actions.

2. Materials and Methods

2.1. Survey area, sample size and parameters studied

Storage losses of maize were conducted by surveying selected households in three districts of Bhutan; Chukha, Dagana and Mongar as shown in Table 1. A major maize growing village was selected in each Gewog and five numbers of households were randomly selected from each of these villages. A total of 30 households were surveyed from each districts (15 households for each storage method).

From each selected households, five numbers of maize cobs were randomly picked and shelled. The total number of grains, total grains damaged by insects and total grains damaged by fungal diseases were counted and recorded from each household. All the grains that have been infested by insects are counted as insect damaged grains and the grains that have been infested by fungal rots are counted as fungal damages.

Table 1.Information showing the study locations, number of households and altitudes

Districts	Gewogs	No of households surveyed		Altitude (masl)
		Storage Method 1	Storage Method 2	
Chukha	Sampheling	5	5	300-350
	Bongo	5	5	1425-1500
	Darla	5	5	1590-1700
Dagana	Karmaling	5	5	150-250
	Tshangkha	5	5	650-800
	Kana	5	5	1250-1600
Mongar	Thangrong	5	5	1400-1500
	Silambi	5	5	1850-1900
	Narang	5	5	2000-2100

The post-harvest storage losses were determined in two different traditional storage methods practiced by farmers in Bhutan. Storage method one corresponds to the practice of storing de-husked maize cobs on the attic floor of their house where as storage method two consisted of hanging the de-husked cobs from the ceilings of their houses. The survey to assess the storage losses was started three months after harvest of maize. The first survey was done in December, second in January, third in February and fourth in March. The survey was conducted three months after storage based on the preliminary survey findings undertaken by the National Post Harvest Center in 2015. This preliminary survey found that major losses occur around three months after storage due to fungal and insect infestations. These months were also selected because maize planting usually starts from March.

2.2. Determination of total storage losses to insects

The total storage loss was expressed in percent as follows;

$$(\%)\ TSL = \frac{A + B}{C} * 100 \qquad (1)$$

Where,

TSL=Total storage loss (%)
A= quantity damage by insects
B=quantity damages by fungal
C=Total grain quantity

2.3. Determining the moisture content of maize grains

The shelled maize grains were filled into the measuring cup of the moisture analyzer (Portable digital moisture meter, A-Grain, India) and moisture content was measured and recorded from each sample.

2.4. Statistical analysis

The data was analyzed by one way ANOVA and the significance of treatment means were compared through Tukey’s test ($P<0.05$) in SPSS version 16.

3. Results and Discussion

Findings from this study show that the major storage loss of maize was due to insect infestation. Regardless of the two storage methods used, insect infestation of grain was the major cause of storage losses. The losses due to storage insect were recorded at 14.91%, 15.79% and 21.99% for Chukha, Mongar and Dagana districts, respectively. Although fungal infections caused significant losses it was lower compared to insect infestation. The storage loss from fungal infection was recorded at 1.27%, 8.03% and 16.22% in Chukha, Mongar and Dagana

Dzongkhags, respectively. The total storage losses recorded after six months of storage in storage method one was 16.18%, 23.83% and 38.21% while total storage losses in storage method two was 8.57%, 23.86% and 37.52% for Chukha, Mongar and Dagana districts respectively (Table 3). The moisture content of maize grains from the study sites was found to be at an optimum level indicating that moisture is not a major issue for maize storage in Bhutan.

3.1 Storage losses between storage methods

The findings showed that insect loss was slightly lower in storage method two compared to loss in storage method one in the surveyed gewogs, but without any significant differences. However, a slightly higher significance loss was observed in Karmaling, Kana and Thangrong Gewogs (Table 2). The slightly lower insect damage in storage method two could be due to better ventilation that resulted in free movement of air that helped reduce insect infestation.

Similarly, loss due to fungal infection was slightly lower in storage method two compared to storage method one except in Sampheling Gewog as shown in Table 2. There was no significant difference in fungal losses between the two storage methods for all the locations except in Tshangkha and Kana Gewogs. The total losses to insect and fungal were in the range of 0.31%-64.65% for storage method one and 0.22% - 59.35% in storage method two (Table 2). The high storage losses in these locations could be due to the traditional storage structures that result in favorable conditions for growth of insects and fungal pathogens. According to Katwal, Dorji and Wangdi (2009), maize grains should be stored at a temperature of 10 ˚C or lower with relative humidity levels between 45% - 55%.

Table 2. Storage losses (%) of maize between two methods of storage in December

Gewogs	(%) Insect		(%) Fungal		(%) Mean	
	Storage method 1	Storage method 2	Storage method 1	Storage method 2	Storage method 1	Storage method 2
Sampheling	$22.26±9.4^a$	$14.04±6.5^a$	$0.79±0.6^a$	$8.08±7.4^a$	$23.05±9.7^a$	$22.12±8.5^a$
Darla	$1.61±0.7^a$	$0.83±0.1^a$	$1.39±1.0^a$	$1.27±0.8^a$	$3.01±1.6^a$	$2.11±0.8^a$
Bongo	$3.44±1.2^a$	$3.93±1.3^a$	$0.66±0.2^a$	$0.34±0.1^a$	$4.11±1.2^a$	$4.27±1.3^a$
Tshangkha	$12.90±1.7^a$	$8.79±0.3^a$	$4.29±0.5^a$	$2.75±0.3^b$	$17.20±2.1^a$	$11.54±0.5^a$
Karmaling	$51.18±1.0^a$	$47.05±0.8^b$	$13.46±0.6^a$	$12.29±0.7^a$	$64.65±1.5^a$	$59.35±1.0^b$
Kana	$45.14±0.5^a$	$42.32±0.7^b$	$6.56±0.3^a$	$4.67±0.4^b$	$51.70±0.7^a$	$46.99±0.9^b$
Narang	$2.66±2.0^a$	$0.79±0.3^a$	$19.18±10.3^a$	$0.16±0.1^a$	$21.85±9.7^a$	$0.95±0.3^a$
Silambi	$0.06±0.0^a$	$0.20±0.0^a$	$0.25±0.1^a$	$0.02±0.0^a$	$0.31±0.1^a$	$0.22±0.1^a$
Thangrong	$26.72±1.0^a$	$14.78±1.3^b$	$0.07±0.0^a$	$0.16±0.1^a$	$26.79±1.1^a$	$14.94±1.3^b$

Means within the rows with different superscript are statistically significant at $P < 0.05$ for each category (Mean ± standard error)

3.2 Total storage losses between districts for each month

The total storage loss from insect and fungal disease was significantly high at 44.52% (storage one) and 39.30% (storage two) in Dagana compared to the other two districts in December (Table 3). The storage loss increased with increased in storage time of the maize except for a decrease in Dagana at the end of storage in March as shown in Table 3. The loss to insect was significantly higher in Dagana compared to that of Chukha and Mongar for both storage types in all the four months. The hot and humid climate of Dagana district could be the contributing factor for high damage and losses. Most of the storage molds and insects grow rapidly at the temperatures between 20-40 °C and a relative humidity of 70% and above (Kumar & Kalita, 2017). The different maize varieties cultivated by people from different districts could also be the reason for higher loss in Dagana. The post-harvest loss was reported to be 26% higher among the farmers growing traditional varieties compared to those who adopted modern varieties in a maize impact study in Bhutan (Shrestra et al., 2006).

Cao et al.,(cited in Dowell & Dowell, 2017) reported that losses of grains including maize can be as high as 20-80% within few months of storage if the insects are not controlled. Mihale et al., (cited in Suleiman & Kurt, 2015) reported that 10-50% of the maize is lost to insect pests while Bankole and Mabekoje (cited in Suleiman & Kurt, 2015) described insects and pests as a major threat to maize losses during storage and on farm.

Meronuck (cited in Suleiman & Kurtt, 2015) reported that losses of maize in various storage facilities in undeveloped tropical countries are in the range of 15-25%. In a previous study by Basappa (2006) the storage loss of maize was found to be 21.86% in Karnataka, India. The study reported long storage duration in traditional structures, insects, fungi and lack of knowledge among the farmers as some of the causes of losses. Similar to their findings, the total storage losses in this survey was 16.18%, 23.83% and 38.21% for storage method one and 8.57%, 23.86% and 37.52% for storage method two for Chukha, Mongar and Dagana districts respectively at the end of storage in March as shown in Table 3. The findings from our survey are also closer to the maize impact study conducted by Shrestra, Katwal and Ghalley (2006) where it was reported that there was an overall post-harvest loss of 20% in the farm survey on maize in Bhutan.

Table 3. Total storage loss (%) of maize in each storage types between districts for each month

District	Storage method 1				Storage method 2			
	Dec	Jan	Feb	March	Dec	Jan	Feb	March
Chukha	10.06^{b}	9.86^{b}	5.41^{c}	16.18^{b}	9.50^{b}	10.36^{b}	10.86^{b}	8.57^{c}
Dagana	44.52^{a}	57.09^{a}	70.99^{a}	38.21^{a}	39.30^{a}	56.30^{a}	68.65^{a}	37.52^{a}
Mongar	16.32^{b}	5.63^{b}	36.18^{b}	23.83^{ab}	5.37^{b}	7.12^{b}	25.96^{b}	23.86^{b}

Mean values in the same column with different superscript are significantly different between districts for each month for storage method one and two, respectively at $P<0.05$ by ANOVA

3.3 Storage losses between storage months within each Gewog

Insect, fungal and total storage loss were determined and compared between the storage months for each gewog. The grain quantity loss to both insect infestation and fungal infection differed between the gewogs. In general, Tshangkha, Karmaling and Kana Gewogs of Dagana district had a higher loss to both insect and fungal disease as shown in Table 4. This could be due to the prevailing hot and humid weather condition in these gewogs. The general trend was that grain loss increased with the increased in storage time except in few cases where it fluctuated between the storage periods. In general, the maize loss due to insect damage was higher compared to losses from fungal damage (Table 4).

Table 4. Month wise grain loss (%) in each category for each Gewog for storage method one

Gewogs	Months	Insect loss (%)	Fungal loss (%)	Total loss (%)
Tshangkha	December	12.90±1.68^{b}	4.30±0.54^{c}	17.20±2.16^{b}
	January	20.84±3.41^{ab}	6.06±0.57^{bc}	26.91±3.88^{ab}
	February	28.94±4.50^{a}	7.57±0.63^{b}	36.50±5.08^{a}
	March	22.40±0.88^{ab}	13.68±1.04^{a}	36.08±1.08^{a}
Karmaling	December	51.19±1.02^{b}	13.46±0.58^{b}	64.65±1.46^{b}
	January	52.44±3.09^{b}	18.60±1.86^{a}	71.04±2.96^{b}
	February	86.21±4.09^{a}	0.30±0.08^{c}	86.51±4.09^{a}
Kana	December	45.14±0.52^{c}	6.56±0.32^{c}	51.70± 0.74^{c}
	January	65.81±3.86^{b}	7.53±0.57^{c}	73.34±3.52^{b}
	February	77.14±2.12^{a}	12.83±1.62^{b}	89.98±1.14^{a}
	March	21.58±0.52^{d}	18.75±1.73^{a}	40.33±1.70^{d}

Mean values in the same column are statistically significant between storage months for each category within Gewog at $p < 0.05$ (Mean ± standard error)

3.4 Storage losses between the Gewogs for each district (Storage method two)

Maize loss in each category was compared between the gewogs for each particular district as shown in Table 5. The gewogs for each district has been categorized as low, medium and high altitude. In Chukha district, Sampheling Gewog located in low altitude had generally higher losses due to damage from insect and fungal infection. The total losses ranged from 22.1%, 25.2%, 24.2% and 12.2% during the months of December, January, February and March respectively. The total losses in Bongo (medium altitude) was 4.28%, 4.72%, 6.21% and 10.8% while total losses in Darla (higher altitude) was 2.11%, 1.10%, 2.12% and 1.90% during the indicated months (Table 5). The results were similar for three gewogs of Dagana district with low altitude Karmaling recording higher losses in December (59.3%), January (79.4%), February (82.6%) and March (56.01%) (Table 5). Kana and Tshangkha had significantly lower losses compared to losses from Karmaling Gewog except for higher loss in Kana during February month. The higher loss in low and medium altitude gewogs could be due to the hot and humid climate that leads to favorable environment for growth of storage insects and fungal diseases.

Kumar and Kalita (2017) described that most of the storage molds grow rapidly at the temperature between 20-40 °C and a relative humidity of 70% and above. In Mongar district, Thangrong (low altitude) and Narang (mid altitude) had slightly higher losses compared to Silambi Gewog (high altitude) as shown in Table 5. Total losses in December was 14.9%, 0.95% and 0.22%, while total losses in March increased to 40.84%, 27.71% and 3.03% for Thangrong, Narang and Silambi Gewogs, respectively.

Table 5. Total storage losses between Gewogs within same district for storage method two

Gewog	Total losses (%) for storage method two			
	December	January	February	March
Sampheling	22.13±8.05[a]	25.26±10.65[a]	24.26±8.76[a]	12.93±3.40[a]
Darla	2.11±0.76[b]	1.10±0.59[b]	2.12±0.76[b]	1.90±0.45[b]
Bongo	4.28±1.34[ab]	4.72±1.22[ab]	6.21±1.52[ab]	10.88±2.19[a]
Tshangkha	11.54±0.49[c]	19.14±2.41[c]	31.81±3.33[b]	28.09±2.28[b]
Karmaling	59.35±1.03[a]	79.43±1.85[a]	82.61±3.08[a]	56.01±5.37[a]
Kana	46.99±0.89[b]	70.35±2.74[b]	91.53±1.69[a]	28.46±1.48[b]
Narang	0.95±0.27[b]	1.92±0.03[b]	39.24±1.92[a]	27.71±0.98[b]
Silambi	0.22±0.09[b]	0.42±0.10[b]	3.15±0.33[b]	3.03±0.31[c]
Thangrong	14.94±1.30[a]	19.01±5.04[a]	35.50±1.61[a]	40.84±0.80[a]

Means in the same column with different superscript are statistically significant between Gewogs within same district at $P < 0.05$ (Mean ± standard error)

3.5 Moisture content of maize

Moisture content of maize sampled from storage method one was in the range of 9.28-13.98% while moisture content of maize from storage method two was in the range of 9.14-13.44% (Figure 1). The moisture content of stored maize grains was found to be within the range recommended for maize storage. This indicates that high moisture content is not a major cause of storage loss in Bhutan. According to FAO (1992), the moisture content of maize for storage is recommended to be between 12-14%. An extension manual on quality maize seed production through community based seed production approach in Bhutan also mentioned the required moisture content for maize storage to be 13% (Katwal et al., 2009). Moisture content is important to ensure good long term storage of maize grains. Generally, higher moisture content leads to increased damage from insects and fungal pathogens (Goudoungou et al., 2017). It was reported by Weinberg et al. (2008) that mold numbers in maize under hermetic storage for 75 days were found to be the lowest when the moisture content of maize was 14% and the mold numbers increased as the moisture in maize increased to 16%, 18%, 20% and 22%.

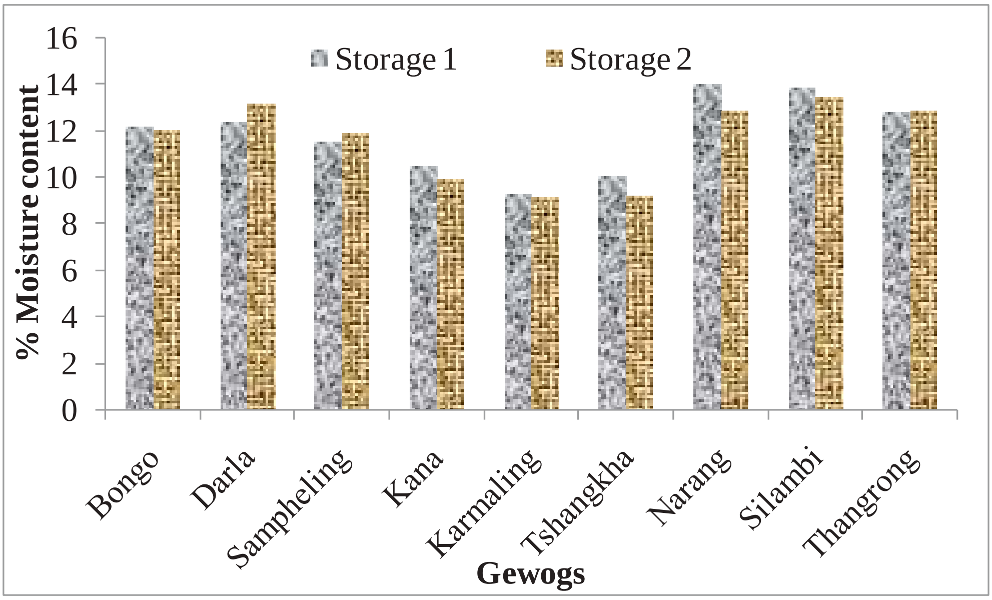

Figure 1. Moisture content (%) of maize grains stored in storage method one and storage method two in December

4. Conclusion

This study showed that there is a high quantity of loss in maize grain during storage. Storage loss was slightly higher in the storage method one but without any significant difference. This study found that the major storage loss of maize was due to insect infestation in both the storage methods surveyed in all the three districts. Regardless of the two storage methods that have been surveyed, losses due to insect infestation of grains were the major cause of storage losses. Maize grain losses due to fungal infection were lower than losses caused by insect infestations. In all the three districts, grain losses were higher in low altitude gewogs in both the traditional storage methods practiced by Bhutanese farmers. Among the three districts, Dagana had significantly higher storage losses in both the storage methods in all the surveyed months. The moisture content of maize grains from the study sites were found to be at an optimum level recommended for long term storage of maize grains.

Improved storage facilities with good ventilation and insect proof system should be designed and introduced to the farmers to minimize the storage losses. Capacity building of farmers on proper harvesting time, techniques and proper handling and storage management will help in minimizing the storage losses. It is recommended that the relevant stakeholders work together and come out with effective storage facilities to minimize storage loss of maize grains from insect and fungal infections.

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Effect of Effective Microorganism (EM) Application and Mulching on the Yield of Japanese Pole Bean (*Phaseolus vulgaris*)

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ABSTRACT

The experiment was conducted with the main objective to determine effect of EM and mulching on the yield of beans at ARDC -Samtenling. The trial was laid in RCBD with four treatments in various combinations of mulching and EM application. EM was applied at the rate 40ml per litre of water at the time of sowing and later foliar application was done fortnightly till the crops were harvested. Yield data, 50% anthesis, days to maturity, pod weight, pod length and pod diameter were recorded. It was observed that treatment T_1 (plastic mulch with EM application) was highest with average yield of 9.68MT per acre followed by T_3 (paddy straw mulch with EM application) with 9.00MT. The Yield for treatment T_2 (plastic mulch without EM application) is 7.29MT/acre. The performance of the control (T_0-without mulch and without EM application) was lowest (4.61MT/acre) with significant difference from the rest of the treatment. There was a positive effect on the germination with highest germination percentage in T1 (99.2%); but there were no significant differences among the treatments. There is no significant effect on the growth parameters, although they performed well with EM application and mulching. EM and mulching had negative effect on number of plants reaching 50% anthesis and days to maturity. To understand the effect of EM alone (and not in combination with mulching), further research is required on the different methods and rates of EM application and its action. Information is also required to establish the role of EM in phenotypic changes crop growth, nutrient content and shelf life of the produce.

Keywords: *Effective Microorganism, Germination percentage, Growth, Yield*

1. Introduction

FiBL & IFOAM (2019) reports that the future of agriculture is intrinsically tied to better stewardship of the natural resources base on which it depends. With increasing scarcity of resources, investment in agriculture has to be managed sustainably so that it is environmentally friendly, economically viable and that it enhances the quality of life. Conventional farming heavily relies on synthetic chemical fertilizers that are costly, unsustainable, and hazardous to health and environment. It is estimated that the United States alone is spending USD10 billion per year on environmental and health care due to use of chemicals (Pimentel et al., 2005). It is claimed that organic farming is more efficient and use 45% less energy in contrast to

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conventional farming that produce 40% green-house gases (Muscanescu, 2013). Over the years people have realized the ill- effects of convention farming and are now shifting towards organic and conservative forms of farming. As of 2017, an estimated 69.8 million of hectares of farms have been brought under organic cultivation with Oceania being the largest (35.9 million hectares) followed by Europe (14.6 million ha) and Latin America (8 million ha) (FiBL & IFOAM, 2019).

The major components of organic farming are manuring, green manuring, mulching, intercropping and integrating microorganism in farming that includes technology like EM, bio-fertilizer, entomopathogen, etc.). Effective microorganism (EM) is the culture of group of beneficial and naturally occurring microorganisms like yeast, lactic acid bacteria, actinomycetes, photosynthetic bacteria and fungi. The concept and the use of those beneficial microorganism was first developed by Professor Teuro Higa of the University of the Ryukyus, Okinawa,Japan, in the early 1980s with the purpose to improve soil health and crop production (Mandalaywala, Patel, & Trivedi, 2017). The culture is usually applied as inoculant to increase the microbial activity of soil and plant. Many researchers have shown that soil and plant application of EM has improved soil health and plant growth resulting high crop yield. The application of EM is not only used in soil and farming but also much exploited in waste restoration and management.Therefore, introduction of mixed beneficial and effective microorganism favours growth, yield and health of crops (Higa & Parr, 1994).

In parallel with organic farming, mulching is another form of conservational farming where many researcher and field data support its role in water conservation and increasing crop production. For instance, significant increase in potato yield was observed with organic mulching (50.226MT/ha) as compared to conventional farming (Momirovic, Misovic, & Brocic, 1997). Percentage soil moisture, vegetative growth and yield were significantly higher in organic mulched banana plots as reported by Bananuka, Rubaihayo & Zake (2000). Plastic mulching is also found to increase yield in okra (8332 kg/ha) with water saving of 52.22% against non-mulching with average yield of 7575 kg/ha and water saving of 31.00% only (Memon et al., 2018). Haque, Jahiruddin & Clarke (2018) reports that plastic mulch can be a suitable tool for enhancing maize production and to maintain good soil health in saline soil. They found the use of plastic mulch to greatly reduce excessive availability of sulphur.

Therefore, study on the effect of soil and foliar application of EM on the yield of Japanese Bean was initiated at Agriculture Research and Development Center, Samtenling. EM technology in Bhutan was introduced by Ministry of Agriculture in the year 1993 and was used in field crops, horticulture and livestock in research centers (Chettri, Thinley, & Chado, n.d). Bean is one of the main vegetables being cultivated in Bhutan. In addition, with the ban of import of vegetables like chili, cauliflower and beans due to high chemical residue, there is a need to findways to increase bean production organically. Further, Bhutan being a small country, Department of Agriculture is focusing on organic production.For the 12th Five Year Plan, organic agriculture is one of flag ship programs implemented by the Department of Agriculture. Khalid et al. (2010) affirmed that application of chemical fertilizer (NPK) deteriorates the microflora inhabiting in the soil while EM application increase the microbial density in the soil. Department of Agriculture with a vision of self-reliant and sustainable agriculture, EM production of vegetableswith mulching technology can be one best approach to organic agriculture and natural farming.

2. Materials and methods

2.1. Location

The experiment was conducted in Agriculture Research and Development Center (ARDC), Samtenling in the month of September for two consecutive years (2017 and 2018). The experimental site is located at 26.90^o N and 90.343^o E and experiences sub-tropical climate with an elevation of 375 m asl. The average maximumtemperature in the month of September is 32.5^{o}C and mean minimum temperature is 19.5^o C. The average monthly precipitation is 1032mm with a relative humidity of 92.8% (NCHM, 2018). The texture of the soil at experimental site is sandy loam.

2.2. Treatment and design

The experiment with four treatments was laid out in a randomized complete block design (RCBD) with five replications. The treatments were: T_1- plastic mulch with EM application, T_2-plastic mulch without EM application, T_3-paddy straw mulch with EM application and T_0-without mulch and without EM application (Control). For the experiment, beans were sown on the 5th of May by dibbling manually. The plot size maintained for the trial was 3m x 2m and seeds were sown at spacing of 40cm x 60cm, accommodating 16 plants in each unit. The distance kept between each experimental unit was 50 cm. During field preparation, chicken manure at the rate 7 kg per bed was applied uniformly to all the experimental units. All other agronomic practices were kept uniform with timely irrigation and weeding. For the treatment T_1 and T_2, plastic mulch with black and silver colour was used. Silver colour was laid up to reflect heat away and to regulate temperature and black colour was laid down to prevent weed growth. Paddy straw mulching was done for T_3 which was spread evenly over the bed until the soil could not be seen. EM was applied at the time of sowing to $T_1$and T_3 at the rate 40 ml per litre and subsequent EM applications were done fortnightly at the same rate until the crops were harvested. Basic research on the effect of different rate of EM application on cabbage was conducted at ARDC Samtenling and the result shows that 40ml/L was optimum for increasing the yield of cabbage. Therefore, the same rate of 40ml/L of EM was applied for beans to study its effect on Japanese pole beans.

2.3. Data collection and analysis

The harvesting commenced from 6th July and a three-time harvest was done.The beans were harvested at horticulture maturity when the pods are mature, fleshy, bright green in colour, and when the seeds are small and green, and suitable for consumption as vegetable. All border crops were rejected for the observation. Data were collected on total yield, pod length, pod diameter, pod weight and 50 percent anthesis. Data were fed to one-way analysis of variance using statistical tool STAR 2.0.1 at 5 percent level of significance.

3. Result & Discussion

3.1. Yield

From the experiment, it was observed that the highest yield per plant was obtained from$T_1$with average yield of 0.72 kg per plant followed by treatment T_3 (0.67kg per plant) but there is no statistical difference between the two treatmentswith EM application which is associated with plastic mulching and organic mulching respectively. In terms of yield per acre, similar observation was made where there is no statistical difference between the treatments T_1 (9.00 metric tonne per acre) and T_3 (9.68 metric tonne per acre). It is stated that with general use of EM, the yield is expected to increase by 20 to 30 percent and even by 50% to 100% in certain cases when applied in soil (Higa & Parr, 1999). The spray of EM (foliar application) on cabbage at the rate 1:5000 at 15 days interval was found to increase cabbage yield by 91.58% more than the control (Yadav, n.d.). In contrast, there is no significant difference in yield between treatment T_2 and T_3. Likewise, there is no significant difference between the acreage yield of treatmentT_2 and T_3. The performance of control (T_0- without mulch & without EM application) was lowest and statistically different from all other three treatments *(P-value*: 0.0017 and 0.0018). The increase in the yield is a result of the combined effect of EM application and mulching. Increase of yield in rice and maize by 4.2% and 13% respectively were reported when the EM was sprayed on the plants at the rate 20 l/ha (Lim, Pak, Jong, 1999). Javaid (2006) also found out that there is 145% increase in the grain yield of peas with foliar application of EM when supplemented with green manure crop. The conclusion was also made by Javiad and Bajwa (2011) that EM should be applied in combination with farm yard manure or recommended dose of fertilizer for better plant growth and yield in mung beans. The high yield of 644 kg/ha in sesame was noticed when mulched with Sudan grass and lowest yield from no mulch (190 kg/ha) by Teame, Tsegay, & Abrha (2017).

Table 1. Comparison of means on the yield

Treatment	Yield per plant (kg)	Yield per acre (MT/acre)
T_1- Plastic mulch with EM application	0.72a	9.68a
T_2- Plastic mulch without EM application,	0.54 b	7.29 b
T_3- Paddy straw mulch with EM application	0.67ab	9.00ab
T_0- Without mulch & without EM application (Control)	0.34 c	4.61 c
P-value	0.0018	0.0017
Treatment Mean	0.57	7.65
CV (%)	21.47	21.47

*Means in columns followed by the same letter are not significantly different

3.2. Germination percentage

EM was applied at the time of mulching before sowing and the results shows that with EM treatment, germination percentage is high with 99.0% and 97.80% in treatment T_1 and T_3 respectively. Germination percentage is also high in T_2 with 98.80% but with no significant differences among the treatments. This confirms that EM application in combination with mulching improves germination. It is observed that coffee seed germinated highest with 76. 47% when sown in forest soil and EM compost mixture at a ratio of 75:46 (Mohammed, Gebreselassie, & Nardos, 2013). In a study by Mowa and Mass (2012), seeds of *Harpagophytum procumbens* when treated with EM gave 32% germination against when treated with sulphuric acid (17%). Germination rate and percentage of mulberry seeds were observed highest in plastic mulch (0.088% and 84.60%) and dried weeds mulching (0.070% and 80.60%) by Wani et al. (2017). Zerga, Alemu, Tebasa, & Tesfaye (2017) also noticed 50% hot pepper seedling emergence in 11 days with grass mulch against 13 days with banana leave mulches. This further substantiates effect of mulching in early germination.

Table 2. Comparison of means on the germination percentage

Treatment	Germination (%)
T_1- Plastic mulch with EM application	99.20
T_2- Plastic mulch without EM application,	98.80
T_3- Paddy straw mulch with EM application	97.80
T_0- Without mulch & without EM application (Control)	96.80
P-value	0.1695
Treat mean	98.15
CV (%)	1.74

3.3. 50% anthesis and days to maturity

The number of plants reaching 50% anthesis was recorded at 36 days after sowing and data shows no significant difference among the treatments (*P- value*: 0.234) (Table 3). However, the least number of plants were observed in treatment T_3 with 11.8 plants followed by T_1 (12 plants). The number of plants reaching 50% anthesis between the treatment T_2 and T_0 is on an average 14.20. Similarly, there is no statistical difference (*P-value*: 00.97) in the days taken to maturity among the treatments. EM and mulching do not have positive effect on the days to maturity and from the data it was observed that maturity was delayed by one day as compared to the treatment without EM application. Days taken for horticultural maturity (69.34 days) in treatment T_1 is at par with the treatment T_2. Similarly, days taken for horticultural maturity are 68.14 days in both the treatment T_3 and control. The application of EM at the rate 1.5 percent has been found to significantly reduce the days to first female flower emergence (59.78%) and days to first fruit picking (67.94%) in a study by Singh, Verma, Rajnarayan, & Singh (2018). Similar observation on delayed flowering was also made by Lu et al. (2018) where rhizosphere EM increases and prolongs the availability of nitrogen. This nitrification process converts tryptophan to the phytohormone indole acetic acid (IAA) which downgrades the genes responsible for flowering.

Table 3: Comparison of means on the growth attributes

Treatment	No. of plants with 50% anthesis at 36 DAS*	Days to maturity	Pod weight (g)	Pod length (cm	Pod diameter (cm)
T_1- Plastic mulch with EM application	12.4	69.34a	15.61	20.34	0.964
T_2- Plastic mulch without EM application,	14.2	69.34a	15.44	20.14	0.948
T_3- Paddy straw mulch with EM application	11.8	68.14 b	14.76	20.4	0.948
T_0- Without mulch & without EM application (Control)	14.2	68.14 b	13.98	19.36	0.936
P-value	0.2344	0.0097	0.5928	0.2899	0.8404
Treatment mean	13.15	68.74	14.95	20.06	0.949
CV (%)	16.47	0.9201	13.67	4.51	5.14

*DAS=Days after sowing

3.4. Quality attributes of the beans

Qualitative characters such as pod weight, pod length and pod diameter were measured. Highest pod weight was recorded in the treatment T_1 with average weight of 15.61g followed by T_2, T_3 and $T_{4;}$ but with no statistical difference. Similarly, there is no significant difference in the pod length. However, average pod length was recorded highest in T_3 (organic mulch and EM application) at 20.40 cm. Likewise, highest pod diameter was recorded in treatment T_1 (0.96 cm) but there is no statistical difference. The lowest pod diameter was noticed in the treatment T_4 (no mulch and no EM application) with average diameter of 0.936cm diameter. Analyses show that there is effect of EM on the quality attributes of beans but they are not significant.

The effect of EM on the growth of onion with respect to growth parameters like plant height and fresh weight of leaves was shown by Fawzy et al, (2012) where yeast was sprayed at 3g per litre of water. The effect of EM on growth was also demonstrated by Górski & Kleiber in 2010 where foliar application of EM increased the number of inflorescence and diameter of rose and number of leaves in gerbera flowers. This is due to EM application and its mechanism of action in plants. Higa (cited in Olle & Williams, 2013) states that EM increases photosynthesis, which enhances the growth of physiological parameters. It also increases uptake of nutrients (N, P, K, Ca, Mg, Fe, Zn, and Cu) as mentioned by Talaat, Ghoniem, Abdelhamid, & Shawky (2014) which improves the growth performance of common beans. Bossuyta and Hendrix (Cited in Joshi, Somduttand, Choudhary, & Mundra, 2019) have shown that EM harnesses energy from sun and uses it to convert organic compound into amino acids, nucleic acids and sugars which in turn promote plant growth. Chantal, Xiaohou, Weimu, & Ong (2010) explain that with EM application leaf area and photosynthesis are increased in cabbage while they are reduced with application of chemical fertilizers. It is also concluded that EM treated bean plants are more efficient in photosynthesis with longer duration of two week as compared to non-treated plants (Iriti et al., 2019). Chowdhury, Islam, Hossain, & Haide (1993) also reported the increase of leaf chlorophyll in string beans with EM application. Application of EM affects the phenology and growth of the plants.

4. Conclusion

Significant effect in terms of yield of beans was due to combined effect of both mulching and EM application. EM application and mulching do not have significant effect on the quality attributes of the beans but there was positive correlation. Positive correlation is also observed in the combined effects on germination percentage with the highest in treatment with plastic mulching and EM application. This research indicates that EM application does not have significant effect on bean yields on its own. Therefore, further research on the effect of different methods and rates of EM application on the crop, and the mechanism of EM effect is required. At the same time, research is also important to study the role of EM in phenotypic changes in the growth of the crop, nutrient content and crop shelf life.

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Farmers' Knowledge on Agrochemicals and Their Use: A Case Study from Tsirang Dzongkhag, Bhutan

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ABSTRACT

This paper is based on the case study on agrochemical knowledge and its usage by farmers of Tsirang Dzongkhag. The data was collected from 205 households out of 5063 through semi-structured questionnaire, informal group discussions and secondary information. Bhutan imported more than 12000 MT of agrochemicals worth over Nu. 6000 million between 2014 to 2017. These agrochemicals were imported from seven countries with almost 100% import from India. More than 20 different types of agrochemicals were supplied to the farmers. The study found that 49.26% of the respondents used one or other form of agrochemicals in 2017. In the last three years 71.04MT (0.54%) of agrochemicals were supplied to Tsirang dzongkhag. Among the agrochemicals supplied, fertilizers (70.58 MT) dominated the supply followed by insecticides (0.25 tons). The least supplied was rodenticide (0.007MT). Per hectare application rate of agrochemicals in 2017 was recorded at 0.0048 kg/ha which was comparatively very low than in other countries. Consumers generally associate farm produces from Tsirang as natural and have gained market popularity. Therefore, to uphold the consumers' health and market niche the use of agrochemicals need to be reduced from the present scenario.

Keywords: *Agrochemicals, Natural, Safety, Import, supply, Produce, Quality*

1. Introduction

Agriculture is paramount in supporting rural livelihood in Bhutan. Achieving food self-sufficiency is the national priority. To achieve this goal various strategies have been adopted from the use of high yielding crop varieties to various agrochemicals such as fertilizers and pesticides. Agrochemicals are those chemicals such as fertilizers, hormones, fungicides, insecticides, herbicides or soil treatment that improve crop productivity.

In Bhutan agrochemical particularly fertilizers and pesticides have been in use as early as 1960s (Kobayashi, Chhetri, & Fukamachi, 2015). Since the introduction of fertilizers, their application was based on the practices in neighboring countries. Only after 2001, standard recommendations were made after the findings of multi-location farmers-extension fertilizer use (NSSC, 2013).

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Gradually with the change in cropping practices, introduction of hybrid crop varieties and change in soil nutrient management practices, there have been changes in both types and amount of fertilizer application.

Insect pests and diseases are a major cause of crop yield losses and their management plays a critical role in providing food security and farming income. The use of plant protection chemicals has also been practiced since the introduction of conventional agriculture in the 1960s. Like in many countries the use of use of agrochemical is guided by legislations such as Pesticide Act of Bhutan, 2000; Pesticide Rules and Regulations of Bhutan 2019.

Despite educating farmers on proper handling of agrochemicals, there are still high chances of over and under usage which may have harmful effects in human health and the environment. Elahi, Weijun and Nazeer (2019) reported that the indiscriminate use of agrochemicals for the maximization of crop yield has adverse effects on the air, water, soil, non-target organisms, and human health. There is no record on or documents of agrochemical usage in the field. Therefore, this study was conducted to assess farmers' knowledge on proper use of agrochemicals and chemicals imported over last three years.

2. Materials and Methodology

2.1. Study site

The study was carried out in Tsirang Dzongkhag which constitutes 12 gewogs. The site is located in the south-central part of the country between the altitude range of 400 to 2000 meters above sea level (masl) between 27^{o} 30'11'' N and 89^{o} 52'42''E.

The dzongkhag has a humid subtropical to warm temperate climate with the mean annual rainfall of 3000-3700 mm. Of the total land area of 638.80 km^{2}, about 78% of the dzongkhag is under forest cover consisting mainly broadleaf and chirpine tree species. The arable land constitutes 13.73% of the total area. According to land registration by type there were 3925.10 ha of dry land, wet land and orchards.

2.2. Sample Size

The survey for the study was conducted from September to December, 2017. There were 5063 permanent households in Tsirang Dzongkhag with a total population of 22,376 (NSB, 2017). The sample households were randomly selected from 12 gewogs. The sample size (n) was calculated following Yamene formula with the margin of error of 7% as mentioned below.

$$n = \frac{\mathbf{N}}{\mathbf{1+Ne^2}} \quad \text{---------------} \text{ I}$$

Wherein, 'n' = Corrected sample size; 'e' = Margin of error; 'N' = Population size

$$n = \frac{5063}{1+5063(.07*.07)} = 205.15 = 205 \text{ Number of households}$$

2.3. Date collection

Primary data was collected through household interview using semi-structured questionnaire. Several group discussions were also organized wherever possible. The information gathered were on pesticide usage in the field, reasons for using chemicals, and farmers' knowledge on application and safety measures, crops most applied with agrochemical, accessibility and awareness on the Pesticide Act of Bhutan 2000. Secondary information on import and supply of agrochemicals were gathered from published papers such as Bhutan RNR Statistics 2017, and Dzongkhag wise pesticide distribution list.

2.4. Data Analysis

Data were analyzed with the help of excel spread sheet and Statistical Package for the Social Sciences (SPSS) package, version 22. The descriptive, frequency and graph were used to determine the numbers of people who used agrochemicals, the crops that were applied with agrochemicals, agrochemicals application, knowledge and who were aware of Pesticide Act of Bhutan.

3. Results and discussion

3.1. National agrochemicals import

Bhutan imported 12,980.48 metric tons of agrochemicals worth more than Nu. 6,000 million from countries like India, China, France, Japan, Thailand, Singapore and United Kingdom from 2015 to 2017 (Tables 1, 2 & 3). India being the major trading partner, almost 99.99% of agrochemicals was imported from there.

Table 1. Quantity of chemicals imported from India and cost incurred during 2015 to 2017

Commodity	Volume (MT)			Value (Nu. In millions)		
	2015	2016	2017	2015	2016	2017
Insecticides	77.44	553.13	53.09	12.24	37.20	18.91
Fungicides	0.00	1.90	1.98	0.00	0.66	0.66
Herbicides	314.00	45.66	0.08	8.52	2.40	0.48
Disinfectants	59.33	88.40	69.93	6.04	8.06	6.89
Other PP chemicals	185.87	132.72	438.80	8.47	5760.28	16.97
Total	636.64	821.81	563.88	35.27	5808.60	43.91

Source: RSD (2017)

During the last 3 years, more than 2,000 metric tons of different plant protection chemicals worth close to 5,800 million was procured. It was in 2016 that maximum quantity of chemicals was imported. However, in 2017 the quantity decreased to 563.9 metric tons.

Table 2. Quantity of chemicals imported from other countries and cost incurred during 2015 to 2017

Commodity	Country	Volume (MT)			Value (Nu. In millions)		
		2015	2016	2017	2015	2016	2017
Insecticides	Thailand	1.32	0.76	0.38	3.70	0.12	0.04
	China	0.06	0.24	0.16	0.00	0.01	0.01
	France	0.00	0.01	0.00	0.00	0.27	0.00
	Singapore	0.00	0.02	0.00	0.00	0.22	0.00
Herbicides	Japan	0.00	0.00	0.02	0.00	0.00	0.03
Disinfectants	United Kingdom	0.05	0.00	0.00	0.15	0.00	0.00
Total		1.43	1.03	0.56	3.85	0.62	0.08

Source: RSD (2017)

Likewise, chemical imported from other countries excluding India was 3.02 metric tons, incurring Nu. 4.55 million in expenditure. The highest import was in 2015 (1.43 metric tons) and thereafter the volume reduced over the years.

Table 3. Quantity of fertilizers imported and cost incurred during 2015-2017

Commodity	Volume imported (MT)			Value (Nu. In millions)		
	2015	2016	2017	2015	2016	2017
Urea	2142.00	2935.15	1196.00	31.38	44.48	17.69
Ammonium sulphate	0.00	0.04	3.50	0.00	0.03	0.03
Ammonium nitrate	0.00	0.01	7.51	0.00	0.00	0.29
Single super phosphate	2888.95	1771.75	0.45	75.27	47.16	0.55
Potassium chloride	0.42	0.42	0.01	0.06	0.10	0.04
Potassium sulphate	0.00	0.13	3.45	0.00	0.03	0.09
Mixture of NPK	2.10	1.00	2.25	0.07	0.05	0.04
Total	5033.47	4708.50	1213.17	106.78	91.85	18.73

Source: RSD (2017)

Among the fertilizers imported urea topped the import volume with 6,273.15 metric tons whereas maximum expenditure (Nu. 122.98 million) was made on purchasing 4,661.15 metric tons of single super phosphate. However, looking at the overall agrochemical import trend it is found that import had decreased from more than 5,600 metric tons in 2015 to just over 1,500 metric tons in 2017 unlike in India where Devi, Thomas and Raju (2017) reported that the agrochemical consumption in 29 states and union territories of India saw a positive growth in trend during 2000 to 2013. In another study by Kalauni and Joshi (2019) trend in agrochemical in Nepal has been found to have increased and in 2016 alone the country imported 635.73 MT (active ingredient) worth more than USD 6.6 million of pesticides.

3.2. Quantity of agrochemical supplied to Tsirang Dzongkhag

More than 20 different types of agrochemicals (insecticides, herbicides, rodenticides, fungicides and fertilizers) have been supplied to the farmers. In the last three years 71.04MT, which is just 0.54% of the national supply of agrochemicals, was supplied to the dzongkhag (Table 4). Among the agrochemicals supplied, fertilizers group (70.58 MT) dominated the supply followed by insecticide group (255.80 litres). The least supplied was rodenticide (7.83 kg).

The per hectare agrochemical application rate in Tsirang was recorded at 0.0048kg/ha in 2017 which was very low compared to other countries. For example, the mean world application rate was 3kg/ha with 0.29 kg/h in India, China (14kg/ha), Japan (11kg/ha) and US (4.5kg/ha) in 2011 (Devi et al., 2017).

Table 4. Quantity of agrochemicals supplied to the dzongkhag in last three consecutive years

Fiscal Year	Fungicides (kg)	Herbicides (kg)	Rodenticides (kg)	Insecticides (l)	Non-toxic chemicals (l)	Fertilizers (MT)
2014-15	2.00	19.23	0.45	81.50	70.00	39.35
2015-16	38.70	17.03	6.78	108.00	0.00	12.45
2016-17	33.10	9.52	0.60	66.30	7.50	18.78
Total	73.80	45.78	7.83	255.80	77.50	70.58

Source: RSD (2017)

3.3. Agrochemical accessibility and application

The respondents reported that sources of chemicals include Agriculture Sales and Service Representative (ASSR), Gewog Extension Centers, Thimphu and Gelephu. Out of 101 respondents who used agrochemicals, 80.19% reported that the chemicals were easily available in the market. Among them 82 respondents said that they procured chemicals from ASSR.

It was also found that fertilizer was mostly applied for paddy and maize crops. On the other hand, more than 80% of insecticides were used in vegetable crops. Respondents also reported that in the recent years, the use of herbicide has increased due to shortage of farm labour force in the villages. The main reason to apply insecticides and fungicides was to enhance production by preventing crop loss to pests and diseases. However, there is a decline in the import of agrochemicals (e.g. herbicide) indicating the reduction of these chemical use in Bhutan (see Table 4). On the contrary, a study conducted in India by Devi et al. (2017) fount that herbicide use has the fastest growth mainly due to rise in wage rage.

3.4. Storage and disposal of agrochemical containers

Safe storage and proper disposal of agrochemical containers is one key area of focus in terms of safety. Agrochemicals are generally incompatible with agricultural ecosystems because all proportion of agrochemical that we use will not be absorbed by the crop and certain percent escape into the environment, and polluting it. Generally, only 20-30% of insecticides are absorbed by crops (Van Der Hoek, Konradsen, Athukorala, & Wanigadewa, 1998). This study had tried to find out how and where farmers store remaining agrochemicals use.

Table 5. Percentage of respondents who practice safe and unsafe storage and disposal

Variables	Safe storage/disposal (% respondents)	Unsafe storage/disposal (% respondents)
Storage of Agrochemicals	79	21
Disposal of containers/ plastics/sacks	68	32

From the survey it was understood that most of the respondents (79%) stored agrochemicals in safe locations like boxes or cupboards under lock and key. Some of the farmers also stored in bamboo where children cannot reach. They also ensured that the agrochemicals are packed in water proof package and maintain air tight to avoid spoilage (Table 5). Likewise, 68% farmers reported that they try to dispose empty containers in pits. They ensured that these disposal pits are located far away from water sources or natural drainage. It was also found that farmers usually do not re-use containers or plastics for other purposes. However, few farmers responded that they re-use fertilizer sacks like those of urea or suphala after cleaning them thoroughly.

3.5. Respondents' knowledge on usage and safety measures

The study indicated that 74.5% of respondents had the knowledge on application dosage and safety measures (Figure 3). According to Singh (2009), only 41% of farmers in western Uttar Pradesh were aware about pesticide hazards. Likewise, in a study by Zhang et al. (2018) in Nigeria, 96% of respondents considered chemicals as hazardous.

Although 74.5% respondents were aware of safety measures, only 66% used protective gears like long sleeve shirt, hat, gloves, mask, goggles, gum boot and apron. It was also found that only 15% respondents were aware of 'The Pesticide Act of Bhutan 2000'. In a report by Mahmoud (2017) about 25% of developing nations in the world don't have proper agrochemical regulations. Even in those countries that have proper rules and regulations, 80% of these nations lack adequate resources to enforce them. As a result agrochemical poisoning is a serious concern in developing countries.

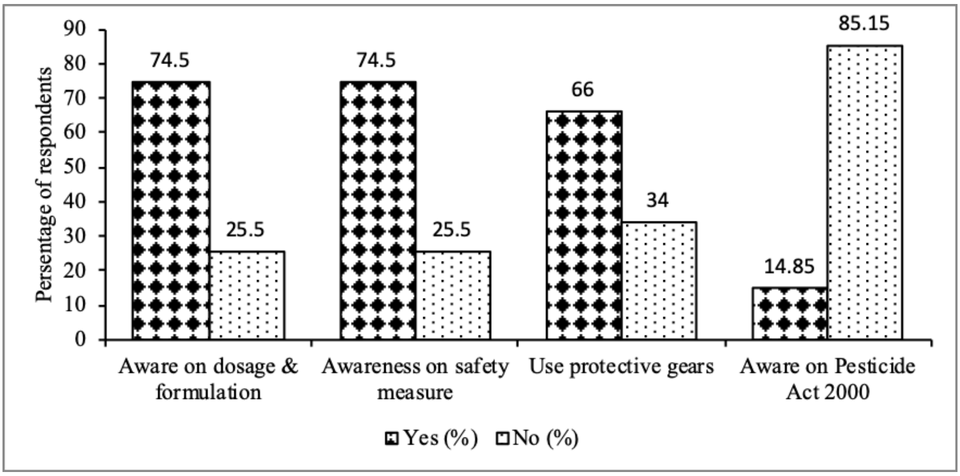

Figure 1. Knowledge on use of agrochemical

3.6. Proportion of agrochemicals usage by crop

The study found that the application of agrochemicals was highest (57%) for cereal crops, particularly paddy (Figure 4). The chemicals applied in cereal crops were fertilizers followed by herbicide and insecticide. Other group of crops was vegetables where insecticide was applied the most. Likewise, in orchards insecticide was mostly used followed by fungicide. This was because these two crops were cultivated in large area. Likewise, minimum agrochemical (4%) (i.e. fertilizers) was used in fodder production.

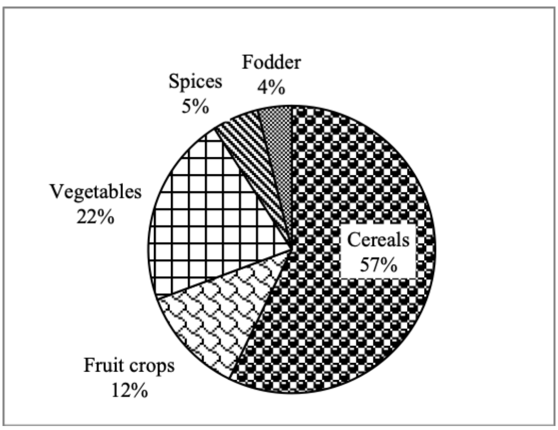

Figure 4. Percentage of crops applied

Fertilizers applied by the farmers were urea (70%) and suphala (30%) only. Among the herbicides, Butachlor (57%) outweighed Glyphosate (43%). In the insecticide use category, 39% of the respondents used Cypermethrin (45%) followed by Fenvalerate (28%). The study also found that 16% of the respondents used bio-pesticide like neem oil as insecticide.

4. Conclusion

Reducing the impacts of agrochemicals on the environment and human health has become very instrumental for agricultural sustainability and cleaner production. Abhilash and Singh (2009) have mentioned that in developing countries the exposure to pesticides causes human health problems such as immune suppression, hormone disruption, diminished intelligence, reproductive abnormalities and cancer. In India, to minimize health hazard from pesticide exposure and reduce residue in several crops, the Indian government implements key strategies such as pesticide safety, regulation of pesticide use, proper application and integrated pest management. The same strategies can be initiated in Bhutan. Prior to 1980s, agrochemicals were procured and freely distributed by the government to enhance agricultural production. However, from 5^{th} and 6^{th} Five Year Plan period many reforms were initiated to reduce the use of agrochemicals through the promotion of integrated pest and nutrient management systems with the support of donor-assisted projects such as the European Union projects.

The government's support to promote organic agriculture and good agricultural practices will reduce the use of agrochemicals in Bhutan. Although less than 50% of the respondents were found using agrochemicals there is still a need to educate farmers on negative effects of their use and try to further reduce the use. Farmers acknowledged that over the years, the use of agrochemicals have increased. This was mainly because of easy accessibility, lack of awareness on pesticide regulations and outbreak of pests and diseases. At the same time government should provide subsidies to those organic farmers by promoting organic plant protection chemicals and manures and higher premium prices for organic produces. Besides, educating our producers and consumers on side effects of chemicals on human, animals and soil health through various means would be another area of focus.

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Guidelines for Bhutanese Journal of Agriculture, Department of Agriculture; MoAF

Content

The **Bhutanese Journal of** Agriculture focuses on original and innovative scientific research relevant to sustainable development of agriculture sector in Bhutan.

Target audience

Papers should address a scientific community interested in agriculture, and cross-cutting themes including; markets, biodiversity, irrigation/water, soils, farming systems and, climate change aspects of sustainable agriculture development in Bhutan.

Types of contribution

Research articles: (5000 – 7000 words) the articles should not have been previously published elsewhere.

Papers should

- Present original and innovative research insights;
- Be well researched and documented
- Clearly describe the research methodology including design and statistical analysis used where appropriate;
- Results should be presented based on sound facts, scientific procedures and well founded arguments;
- Be embedded in the relevant local, national or international debate;
- Refer to the most recent academic literature on the issues discussed;
- Be presented in a clearly structured and comprehensible manner; in the interest of disciplinary and interdisciplinary communication.

Short communication (2000-4000 words): A concise and complete with description of an investigation. The bulk of the text should be organized in a continuous form with separate sections such as Introduction, Materials and Method, Results and Discussion. It should, however, include a short Abstract and a list of keywords at the beginning of the communication, and Acknowledgements (if any) and References at the end. These components are to be prepared in the same format as used for full-length research papers.

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Author(s) and agency

The names of the author (s) should be written in full. Indications of titles, professorial ranks or other professional titles should not be used. The address of the agency to which the author belongs to shall be written as footnote. Please provide the email address of the first corresponding author only in italic, **8** Times New Roman.

Abstract and key words:

The abstract consists of **150 – 300** words in one paragraph. The abstract should summarize pertinent results in a brief but understandable form. The abstract should start with a clear statement of rationale, brief objectives of the experiment/research/study and methods, results and must conclude with one or two sentences that highlight important conclusions. References are never cited in the abstract. Abstract should be indented by **0.2** inch on left and right and centre justified with **12** point italic, Times New Roman. Below the abstract, list three to five key words that best describe the nature of the research.
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The introduction starts on a new page following the abstract. The introduction briefly justifies the research and specifies the hypotheses to be tested. Discussion of relevant literature should be cited to support/justify your research in the introduction. Introduction should be divided in to concise paragraph, each paragraph dealing with a topic of your research theme. Mention of objectives of the study or research will be not done under separate heading. If at all necessary, it can be included in the introduction. Objectives should be clear, concise and realistic.

Materials and Method

Materials and Method should be clearly described in a step-by-step guide for others to understand and follow.

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Statistics: The data should be analysed using standard statistical model. The use of incorrect or inadequate statistical models to analyze and interpret data is not acceptable. The statistical model, classes, blocks, and experimental unit must be described. Statistical test (S) used should be clearly stated. Both confirmatory inferential statistics such as LSD, *r*-value, 95% CI, etc should be at P-value of 95% confidence level and descriptive statistics such as standard error, standard deviation, CV%, etc should be given where appropriate.

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Results should be presented in tabular or graphical form with description of key results in the text. The text should explain or elaborate on the tabular/graphical data, but numbers should not be repeated extensively within the text. Sufficient data with index of variation should be presented to allow the reader to interpret the results of the experiment.

Discussion should interpret the results clearly and concisely and should integrate similar literature results with the research findings to provide the reader with a broad base on which to accept or reject the hypotheses tested.

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This section should consist of **300-500** words. Conclusion section should highlight key findings and their implications to relevant users of the information. It should explain in lay terms, without abbreviations, acronyms, or citations, what the findings of research/study are. Do not repeat statements made in the result and discussion sections.

Acknowledgement

Acknowledgement should be made to key persons other than authors and co-authors including the anonymous reviewers and funding agencies. However, it should not be lengthy.

References

Tables and Boxes

Tables are used to present numerical data in a self-explanatory manner. They should be intelligible without consulting the text and should not duplicate data already given in the text or in illustrations. Any abbreviation used in a table must be defined in that table. All tables should be cited in the text. Arabic numerals are used to number tables. The table number (i.e. Table 1) is typed followed by a period. The title of the table should be given just above the table with only the first letter capitalized; font 12 Times New Roman. Do not use a period at the end of the title. Column headings should have the first letter of each word capitalized while the names of variables are typed with only the first letter capitalized (i.e. Average growth rate). For numerals less than 1, insert a zero to the left of the decimal point (columns should be set up so that decimal points are aligned). If there are no data for a particular entry, insert a dash. If an explanation is necessary, use an abbreviation in the body of the table (e.g. NA) and explain clearly what the abbreviation means.

- In boxes, include caption in a title bar (topmost line across entire box)
- Your submission may have no more than 5 tables or boxes in total
- Very large tables and long lists should be avoided.
- No border lines, only boundary lines will be used, 11 point, Times New Roman and no colors
- Text in tables must always be horizontal; no bold.

Example

Table 1. Mean growth rate of chilli plants

Treatments	Plant height (cm/plant)	No. of leaves per plant	Stem girth (mm/pant)	Yield (kg/plant)
Poultry manure	145	78	10.5	144
NPK	132	76	9.2	128
Cow manure	128	64	8.9	121
None	93	21	9.8	108

Figures

- Possible file formats: .JPG, PDF, .XLS, .GRF.
- Figures should be black and white print
- The submission should not have more than 5 figures (including photos, diagrams, maps)
- Put captions below the figures; 12 point Times New Roman
- No color, but choose different shade(s) that is appropriate for black/white printing
- Photos, illustrations, flow charts can be used if necessary

Example (Figure 1)

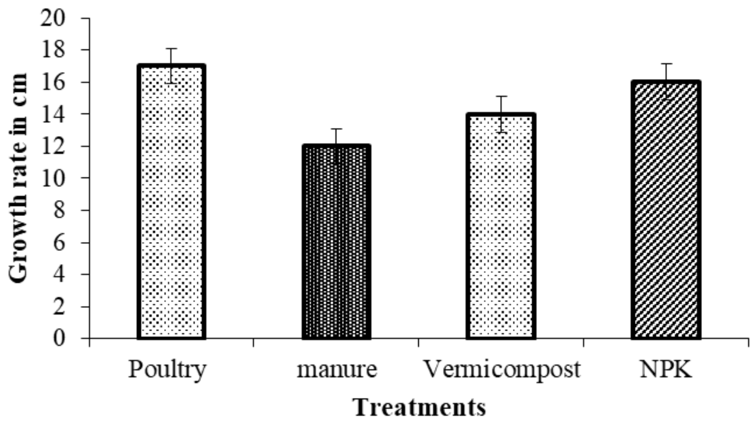

Figure1. Effect of treatments on growth rate of broccoli plant

Note: For editorial convenience, authors are also required to submit charts (figures) and tables as separate files with appropriate corresponding file references as they appear in their manuscripts.

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All literature cited in any part of your paper should be listed at the end of the body text file in a section entitled "Reference," without numbering. The references should be arranged in alphabetically by author and then chronologically, giving the complete unabbreviated source citation.

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For convenience and ease of use for our contributing colleagues in the research centres and our field personnel, BJA has adopted the APA (6th) style of referencing.

In-text references

Use author–year style in chronological, then alphabetical, order. Use "et al" with three or more authors. Use colon and number to indicate page reference.

Examples:

Karma (1993, 1995a, 1995b)

- Yuden and Dorji (2004)
- (Sonam et al., 1975)
- (Stremlow 1998; Antrop 1999; Tress and Tress 2001; Backhaus et al., 2007a, 2007b)
- (see figures 4 and 5 in Keen et al., 1971)

- Wangchuk et al. (2014)

Campbell (1993: 55);

- **Three or four authors**: Where there are three or four authors, all surnames should be used the first time the in-text reference appears in the document. For all subsequent citations, include only the surname of the first author followed by **"et al."**

First mention:

- Smith, Grierson, Malthus, and Nicholson (2015) found . . .
- According to evidence . . . (Smith, Grierson, Malthus, & Nicholson, 2015).

Subsequent mention:

- Smith et al. (2015) suggest . . .
- The study concluded . . . (Smith **et al.**, 2015).

- **Five, six or seven authors:** Where there are five, six or seven authors, use the first surname only followed by et al.
  - According to Abercrombe et al. (2008) . . .
  - It was shown that . . . (Abercrombe et al., 2008).
- If there are several works by the same author(s), they should be arranged chronologically by year of publication with oldest reference first; if several works by the same author were published in the same year, arrange them alphabetically and add a letter to the year of publication, e.g. 1999a, 1999b, etc
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In-text:

- (NBC, 2014); NSB (2014)
- MoAF, 2017); MoAF (2017)

End-text:

NBC. (2014). *Biodiversity Action Plan* Thimphu: National Biodiversity Centre (NBC), Ministry of Agriculture & Forests.

MoAF. (2017). *Agriculture Statistics 2017*. Thimphu: Ministry of Agriculture and Forests (MoAF), Royal Government of Bhutan.

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Sample References

Journal article

Antrop, M. (1999). Background concepts for integrated landscape analysis. *Agriculture, Ecosystems, and Environment*, 77, 17–28.

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