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The first volume of the Bhutanese Journal of Agriculture is launched to commemorate the 38th Birth Anniversary of His Majesty the 5th King Jigme Khesar Namgyal Wangcuck, 2018

FOREWORD

The Department of Agriculture is pleased to publish the first ever version of "Bhutanese Journal of Agriculture". Under the scope of Council for RNR Research of Bhutan (CoRRB), the ministry published the "Journal of Renewable Natural Resources of Bhutan" until 2014 encompassing research findings from all departments within the ministry. After the dissolution of CoRRB, the mandate for agriculture has been transferred to Agriculture Research and Extension Division under Department of Agriculture. We are delighted to revive the publication that will compile research findings primarily from agriculture sector.

The Bhutanese Journal of Agriculture is initiated to provide a platform for researchers to share their findings to wider audience for work conducted in Bhutan. The journal is expected to motivate Bhutanese researchers and field colleagues to develop a habit of scientific writing and contribute to knowledge management. Through proper documentation, the work can be used for future reference and avoid reinventing the wheel. We envisage that the research findings will lead to transfer of technologies for adoption by farmers.

I would like to thank the authors for their contribution and the reviewers for their critical feedback. Furthermore, I would like to extend my appreciation to the Editor-in-Chief and team for successful publication of the journal. Over time, we must strive to attain international standard of our articles.

Tashi Delek!

Kinlay Tshering (Ms.)

Director

EDITORIAL

We are indeed delighted to publish the inaugural issue of the Bhutanese Journal of Agriculture (BJA). The void in the publication of scientific papers on agriculture, created after the abolition of the Council for RNR Research of Bhutan (CoRRB) which used to publish the RNR Journal of Bhutan, will expectantly be filled by BJA. Unlike the RNR Journal, BJA exclusively focuses on agricultural research and development; agriculture connotes field crops (food cereals, oil crops and grain legumes) and horticulture (fruits, vegetables and spices) in our context.

This edition of the BJA includes articles on food crop agronomy, variety evaluation and development, propagation methods in fruit plants, participatory vulnerability assessment, economic analysis of crop production as well as processing. Climate change is increasingly becoming a germane and imperative topic of study and discussion. Two papers on the potential impact of climate change on horticultural production and rice crop suitability model under the future climate scenario make interesting reading. Aeroponics, a relatively new technique in Bhutan, is successfully demonstrated to produce potato mini-tubers. Likewise, community based seed production of maize; introduced only in recent years has helped farmers in the East to improve their livelihood through enhanced quality of seed, bigger harvest and thus additional income. Phenotypic characterization and diversity studies on banana and common beans reflect another dimension of crop breeding and variety development. Apart from articles on biological science, the journal also contains a social science paper on the evaluation of a JICA-implemented horticulture project in Eastern Bhutan and how it helped farmers to boost their happiness level.

BJA provides the perfect platform for our young researchers and agricultural extension and development workers to showcase their work and achievement not only to the scientific community but also to a larger audience of policy formulators, decision makers and those responsible for our career advancement. In today's competitive world, scientific publications matter in contending for a scholarship or a job outside the civil service. Thus, we have to cultivate the habit of writing and instil the zeal of publishing, as never before. Indolence and apathy are no more bliss or bearable attitude. The journal also serves as a powerful vehicle for advancement of agricultural science and dissemination of technologies. We encourage contributions in any field, whether biological, social or economic, which will aid in our understanding of agriculture.

We wish you a very happy reading.

Mahesh Ghimiray

Editor-in-Chief

ABOUT THE JOURNAL

The Bhutanese Journal of Agriculture (BJA) founded in 2017 is published by the Agriculture Research and Extension Division, Department of Agriculture, Ministry of Agriculture and Forests. The journal will publish quality research articles annually. It is an open access English language journal on Agriculture and financed by the Royal Government of Bhutan. It aims to provide a coherent mechanism through which appropriate technologies, information and knowledge in the agriculture sector can be generated and made available to clients.

The BJA focuses mainly on original and innovative scientific research relevant to sustainable development of agricultural sector in Bhutan. The papers addresses 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.

The journal article structure conforms to scientific standards. Results are critically analyzed and objectively presented. The standard guide to authors of BJA is attached at the end of this book. BJA does not charge any fee for submission of articles. Once the Department of Agriculture's webpage is developed, the online publications will have Open Access.

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CONTENTS

Participatory varietal selection of potato and agronomic performance with farmers' feedback on new varieties

Yadunath Bajgai[a], Tshering Dochen [a], Pema Wangchuk[a], Mohinder S. Kadian[b], Thomas Z. Felde[c], Mathelde Lefebvre [d], Lobzang [a], Sushma Arya[b], Sangay[a] , Tashi Wangdi[e], Tashi Gyeltshen[a] and Namgay Wangdi[f]

ABSTRACT

Potato (Solanum tuberosum L.) is one of the widely produced, consumed and traded horticultural crops in Bhutan. Hence, potato cultivation has helped to transform the Bhutanese agriculture from subsistence to an emerging market-oriented agriculture. However, its productivity has remained stagnant over the years due to lack of varietal diversity and degeneration of seed quality. Therefore, variety development research was conducted to increase yield and provide alternative varieties. The advanced evaluation trial using mother and baby approach was conducted using suitable International Potato Center (CIP)-originated potato clones of 399053.11, 394034.7, 394611.112, 396034.268, 397196.3, 392797.22 and 303381.30 and Desiree as the local check (control) at Bumthang and Khangma in 2015. Following the evaluation and release of a new potato variety, three demonstration trials were conducted in Chukha, Haa and Wangdue districts to compare the yields of two new varieties with Desiree. When the clones were assessed based on yield and preference ranking by the farmers, 397193.3 and 392797.22 clones outstood as high yielders and most preferred ones, while 394034.7 was considered as the least yielder and least preferred clone in Bumthang. The two clones (397193.3 and 392797.22) had significantly ($P<0.05$) high yield and were the most preferred ones compared to Desiree in both the mother and baby plots. Having fulfilled all the research requirements, 392797.22 were released in June 2017 as Yusi Maap to address yield stagnation, as an alternate red-skinned variety. Besides being a micro-nutrient-dense variety, Yusi Maap has moderate resistance to late blight. In three demonstration trials, Desiree yielded the least among the three varieties. Analysis on the farmers' preference ranking showed that Yusi Maap was most preferred in three locations probably due to the red skin and better yield. The results of this study is has potential to positive impact potato production and enhance farmers' livelihood through higher yields.

Keywords*: Participatory varietal selection, Bhutan, Yusi Maap, organoleptic assessment, malnutrition*

1. Introduction

Globally, potato (*Solanum tuberosum L.*) is the fourth most important crop after wheat, rice, and maize. Apart from its wide adaptability, it has the capability to provide more nutritious food from less land in less time than other crops such as wheat, maize or rice (CIP 1984). In

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Bhutan, potato is one of the widely produced, consumed and traded horticultural crops (Department of Agriculture 2017). This is possibly due to the existence of favorable conditions for growing high quality potato in the country. (Joshi & Gurung 2009). Potato is mostly grown between 2000 and 3500 m above mean sea level (m.a.s.l) and is the most important crop for the farmers living above 2500 m.a.s.l. (Roder et al 2008). About twenty two percent of the rural households cultivate potato as it is the only non-cereal food crop, cash crop and vegetable. It contributes to rural household income more than any other horticultural crops (RNR Census 2000). Over the past four decades, potato cultivation has picked up fast and has transformed the Bhutanese agriculture from subsistence to an emerging market-oriented economy (Roder et al 2008). Famers in some Dzongkhags, for example, Bumthang and Haa rely on potato crop for their livelihood since they buy cereals through the sale proceeds of potato and thus potato acts as food crop indirectly. The sale of potato generated about Nu. 797 million in 2016 and is the highest revenue-earner amongst the agricultural commodities in Bhutan (Department of Agriculture 2017) and there is further potential to increase the revenue. Average yield and production of potato from 2012 to 2016 was 9.64 ton/ha and 51,034.4 ton, respectively (Table 1). The potato yield slightly increased from 2012 to 2014 but it dropped in the following years (Table 1). Besides stagnation of yield, the crop productivity in Bhutan is one of the lowest in the South Asian region as yields in Bangladesh, India and Nepal were 19.4, 22.9 and 13.7 ton/ha, respectively, in 2014 (FAO, 2014).

Table 1. Cultivated area, yield and production for 2012 to 2016

Year	Cultivated area (ha)	Yield (ton/ha)	Production (ton)	Source*
2012	5,078.11	8.47	43,000	Agriculture Statistics 2012
2013	5,419.26	9.30	50,390	Agriculture Statistics 2013
2014	5,174.02	10.36	53,612	Agriculture Statistics 2014
2015	4,859.57	10.16	49,358	Agriculture Statistics 2015
2016	5,923.51	9.93	58,822	Agriculture Statistics 2016
Average	5290.89	9.64	51,036.4	

* Annual publications (2013 to 2017) of the Department of Agriculture, Ministry of Agriculture and Forests

The stagnation of potato productivity of potato in Bhutan is due to lack of diversity of varieties and degeneration of potato seed quality. Hence, there is a need to carry out variety development research to increase the diversity of varieties for the growers for increased production. This is because through improved management and better germplasm the productivity can be enhanced as our current productivity (Department of Agriculture 2017) is less than half of the productivity in India in 2014 (FAO 2014). Therefore, the main objectives of this study were to evaluate different potato genotypes that were received from the International Potato Centre, Lima to identify the most promising varieties through participatory varietal selection (PVS) and conduct demonstration trials in farmer's field to showcase the yield potentials of these new varieties for better adoption. Since farmers are the ultimate users of the potato varieties participatory research methodology is adopted to

holistically include social preferences along with scientific traits like yield potentials, disease resistance, nutrient content and so on. Due to participatory nature of conducting research, farmers are likely to adopt new varieties after the formal release. This study is anticipated to address the problem of yield stagnation and contribute to increasing potato production in the country.

2. Materials and methods

In 2015, advanced evaluation trials were conducted on-station (mother trial) and on-farm (baby trial) in Choekor block under Bumthang district (2650 m.a.s.l) representing high altitude agroecological zone and in Khangma (2100 m.a.s.l) under Trashigang district representing mid-altitude agroecological zone (Wangckuk et al 2014). The experiments were laid out in a randomized complete block design (RCBD) with three replicates in mother trial whilst baby trial consisted of plantings in three different locations in farmers' field. The advanced evaluation trial was conducted using the CIP originated potato clones of 399053.11, 394034.7, 394611.112, 396034.268, 397196.3, 392797.22 and 303381.30 and Desiree as the local check (control). For both mother and baby trials, identical plot size of 2.8 m^2 (2 m x 1.4 m) was maintained for each treatment and twenty tubers were planted in two rows per treatment. Land was ploughed with power-tillers and ridges were made manually. Potato tubers were planted with a distance of 20 cm between the plants and 70 cm between the rows. The crop was fertilized based on the nutrient recommended rate i.e. 79:89:40 N:P:K kg/ha (NSSC 2013). Farmyard manure was also applied at 12 ton/ha. The crop was grown under rain-fed condition and no plant protection measures were required.

Participatory varietal selection (PVS) workshop was conducted both at flowering and harvesting stages in both the trial locations. However, only the PVS data for harvesting stage in Bumthang is presented here in detail. PVS in Bumthang was conducted on 13th August 2015 and 27 farmers (seven men and 20 women) participated in the PVS workshop. During the PVS exercise, yields were measured and social evaluation (preference voting) was conducted using standard PVS procedures of CIP. The PVS event was organised jointly by the scientists of CIP Regional Office in New Delhi and National Potato Program (NPP). The participants were explained about various exercises involved in the PVS. Gathering and ranking of plant criteria like appearance, crop health at harvesting stage and ranking of preferred clones through casting individual votes. The participants were informed about different CIP clones of potatoes available in Bhutan and how the different genetic material differs in tuber shapes and colour, vegetative characteristics, biotic and abiotic stresses, and nutrient content. They were also explained on how to list and rank preferred vegetative criteria. At the harvesting stage, morphologies like tuber shape, eye depth, skin colour, tuber uniformity, yield and pests and disease tolerance were assessed. Participants' opinions were taken for preferred clone/variety. Each of these criteria was written on the board as the farmers were answering about the preferred characteristics. These listed criteria were ranked as per participants' choice. Each of the above criterions was written on a paper and kept on the table in front of a plastic bottle. The participants ranked the criteria by casting a vote for the three most important criteria based on their preferences. Women and men participants were given 6 bean and maize seeds, respectively to cast their votes i.e. 3 seeds for the first

most important clone, 2 seeds for the second, and 1 seed for the third important clone as per their choice. The same procedure was repeated for all 3 replications of mother trial on-station. Similar voting procedures were used for the three baby (on-farm) trials in the farmers' field. The result of the votes per clone was counted and the clones were ranked based on the number of votes received. Yield and vote data generated were analyzed using Highly Interactive Data Analysis Platform (HIDAP) software developed by CIP (CIP 2017) to assess the farmers' preferences. Microsoft Excel was used to generate graphs and compute standard errors for the research trials.

In order to effectively disseminate information on newly released varieties, demonstration trials in farmer's field is necessary. In this regard, three demonstration trials were conducted at Lobnekha (Chapcha, Chukha), Esu (Haa) and Baylanda (Kazhi, Wangdue) in 2017. The demonstration sites were selected in consultation with respective Dzongkhag and geog staff. Each demonstration was laid out in a selected individual farmer's field. Each demonstration site was provided with 50 kg seed of three varieties, namely, Nasephey Kewa Kaap (NKK), Yusi Maap and Desiree (standard check). The demonstration sites were provide with one set of irrigation equipments (one roll each of HDP pipe and flexible, and one sprinkler) to facilitate irrigation. The trials were established during January and February 2017 and were managed by the farmers with technical backstopping from the Agriculture Extension Supervisor (EAS) and National Potato Program. Field days were conducted during the harvest of potato in July and August 2017. Crop agronomic performance was measured using yield and farmers' feedback on preference which was scientifically assessed using voting method as in the case of mother and baby trials. The results were shared with the participants during the field day at each demonstration site.

3. Results and Discussion

As PVS involves both scientific measurements and social evaluations, it has emerged as the best method to identify farmers' preferred crop varieties and their popularization. PVS helps farmers to get familiar with adoption of new varieties and helps researchers in decision making. Among the seven selection criteria, high yield was identified as the most important criterion with 78 votes (20 males and 58 females' votes) followed by medium and uniform size with 29 votes (Table 2). On the other hand, scab resistant and chipping qualities were the least important criteria with seven votes each.

Table 2. Farmers' criteria of potato genotype selection in Bumthang

Sl/No.	Criteria	Score (Men)	Score (women)	Overall score	Rank
1	High yield	20	58	78	1
2	Oblong shape	7	2	9	5
3	Floury texture	1	10	11	4
4	Medium and uniform size	6	23	29	2
5	High nutrients	4	17	21	3
6	Scab resistant	2	5	7	6
7	Chipping quality	2	5	7	6
	Total	42	120	162	

Analysis of variance of the PVS yield data shows that the genotypes were statistically (P<0.05) different in terms of yield and farmers' preference (Table 3). Potato tuber size distribution of the genotypes for mother trial is presented in Figure 1 and that for baby trial in Figure 2. Results of statistical analysis (Table 3) show that commercial yield (i.e. combination of seed size and table size) of the clones 399053.11, 394611.112 and 392797.22 did not differ significantly (P<0.05) among them. Further, 394034.7, 396034.268 and Desiree were also statistically not different (P<0.05). However, the yields of 397196.3 and 392797.22 clones were significantly higher (P<0.05) than Desiree in both the mother and baby trials. Similar findings were also found for non-commercial yields that comprise tubers of <30g weight per tuber. Based on preference ranking, 397196.3, 392797.22 and 399053.11 clones received the maximum votes both in mother and baby trials (Figure 3) and this implies that they are the most preferred clones among treatments in the trial. Further, the chi-square analysis on the preference ranking votes (Table 3) indicated that 397196.3, 392797.22 and 399053.11 outstood from among other clones in the mother trial but were not significantly different (P<0.05) from Desiree in the baby trial.

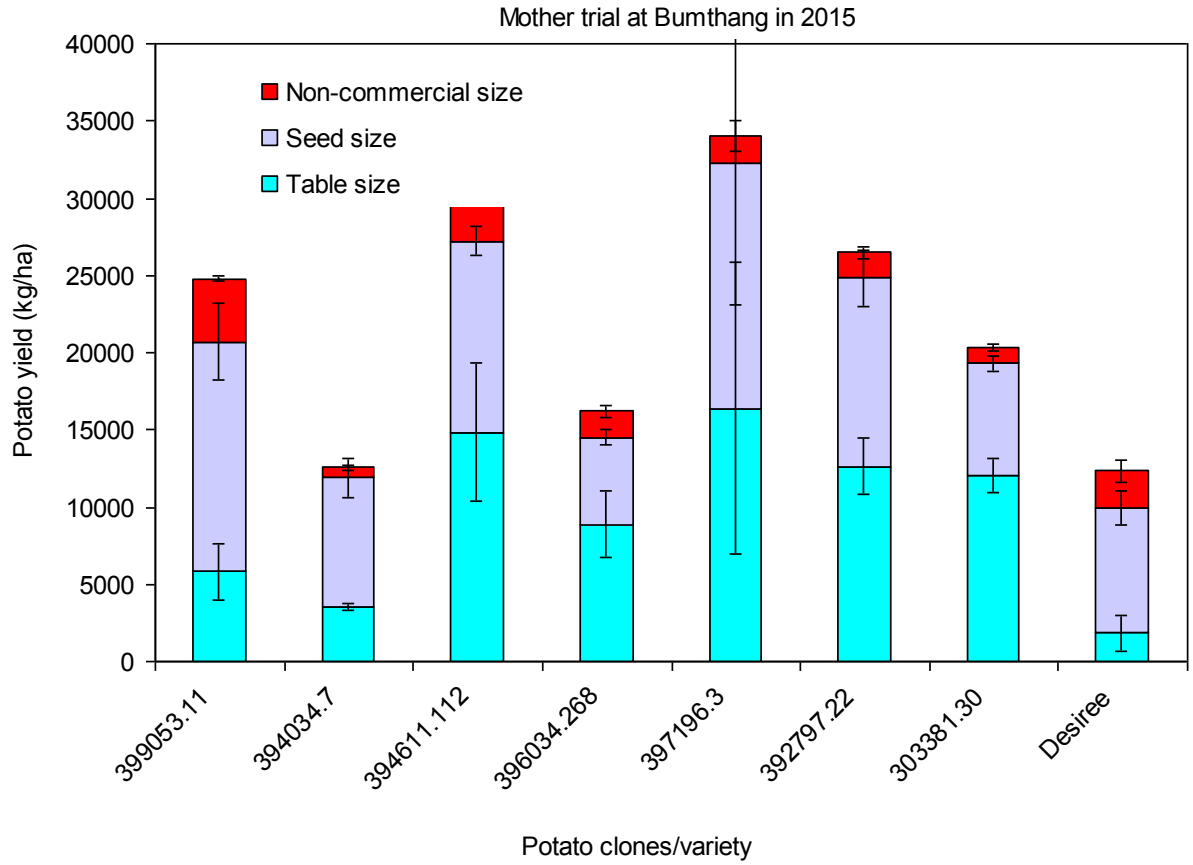

Figure 1. Yields of potato clones/variety from the mother trial at Bumthang. Values are means of three replicates and error bars show standard errors of the means each tuber size. Table size = >65g/tuber' Seed size = 30-65 g/tuber and non-commercial size = <30g/tuber

On an average, the new potato clones yielded 23.4 ton/ha (ranges 12.6 to 34.0 ton/ha) and Desiree, the local variety, yielded 12.3 ton/ha in the mother trial. However in the baby trial, the average yield for the new clones and Desiree was 21.4 ton/ha (ranges 5 to 37.3 ton/ha)

and 21.5 ton/ha, respectively. Among the clones, 397196.3 performed the best in the mother plot whilst 392797.22 did best in the baby trial. In both the trials, least yielding clone was 394034.7 with yield lower than that of Desiree. In terms of social assessment, the most preferred clone was 397193.3 and least preferred was 394034.7 in the mother trial. However, when the clones were assessed against yield (Figures 1 and 2) in combination with preference ranking (Figure 3), 397193.3 and 392797.22 were better clones. The two clones had significantly high (P<0.05) yield and were the most preferred ones than Desiree (control) in both the mother and the baby plots. For instance, the average yield of 392797.22 was 88% (15 ton) higher and received more than 8 times preference votes than Desiree. Similar results were also found at Khangma. Such similar pattern was also observed at both Bumthang and Khangma in 2014.

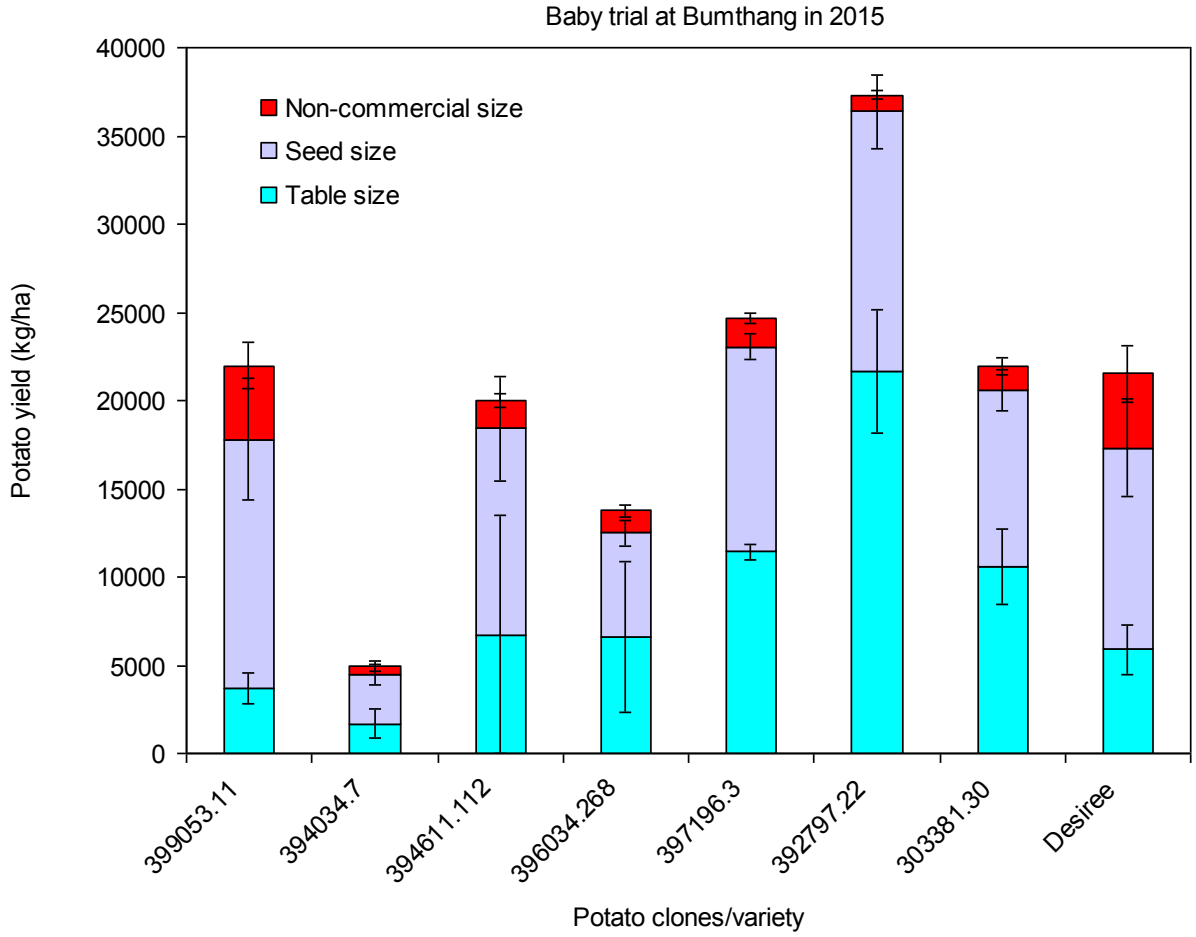

Figure 2. Yields of potato clones/variety from the baby trial at Bumthang. Values are means of three replicates and error bars show standard errors of the means each tuber size. Table size = >65g/tuber Seed size = 30-65 g/tuber and non-commercial size = <30g/tuber

For potato growers the distribution of potato sizes and uniformity is also important besides high yield (Table 2). This is because they need large tuber size for table purpose or consumption and medium size for seed purpose and to sale as seed to other famers (Roder et al 2008). Though smaller in size, the seed size potato earns better prices than the table size potato (Luthra et al 2006) since seed potato is in high demand for planting. From looking at

the distribution of sizes, 399053.11 and Desiree have larger proportion of non-commercial tuber sizes (Figures 1 and 2). The least proportion of non-commercial tubers is found in 394034.7 and 392797.22 in (Figures 1 and 2) which is interest to the growers as the lowest proportion of the total productivity can be non-commercial in value. Based on synthesis of research results, a relatively high yielding (Figures 1 and 2) and moderately preferred (Figure) 392797.22 (red-skinned) was selected for release to farming community. This was selected because it is red-skinned (Bhutanese farmers prefer for the red skinned potato (Roder et al 2008), its observed moderate resistance to a common problem of late blight and its micro-nutrient dense characteristics. It is difficult have all required traits in the same clone and choice of 392797.22 was based on critical analysis of aspects of our potato industry including consumer health. Further, yields of 399053.11, 394611.112, 397196.3 and 392797.22 are comparable to that average yields in neighbouring countries (Bangladesh - 19.4, India -22.9 and Nepal -13.7 ton/ha) (FAO 2014) and are better yielding than our national averages in the recent times (Table 1). In the basic terms, it means that get better yields can be achieved if some of these clones grown on a commercial scale. In other words, better yields can be achieved if some of these clones are grown on a commercial scale.

Based on this study in two locations for two years, clone 392797.22 was proposed for release and was released as a new variety, called Yusi Maap, in 2017. The new variety is expected to address the yield stagnation issue and provide an alternate variety to red-skinned variety to the growers and consumers. Yusi Maap is moderately resistant to late blight which is a major plant protection issue in Bhutan as the other varieties grown in Bhutan are susceptible to late blight except Nasephey Kewa Kaap. According to the International Potato Centre, Lima, it has high Iron (> 18.45 mg/kg dry weight basis), high Zinc (> 16.5 mg/kg dry weight basis), and moderate vitamin C (59.85 to 89.7 mg/100g dry weight basis) content. Hence, the nutrient-dense trait of this variety is expected to address malnutrition like anaemia in children and women, whose diet consists of some potatoes in one form or the other. This is the first micro-nutrient dense variety released in Bhutan and is expected to revolutionize consumption pattern because of the stereotype thinking that potato can only provide carbohydrates. However, the major challenge now is to produced enough seeds (seed rate 2 ton/ha) to meet the requirement of the growers.

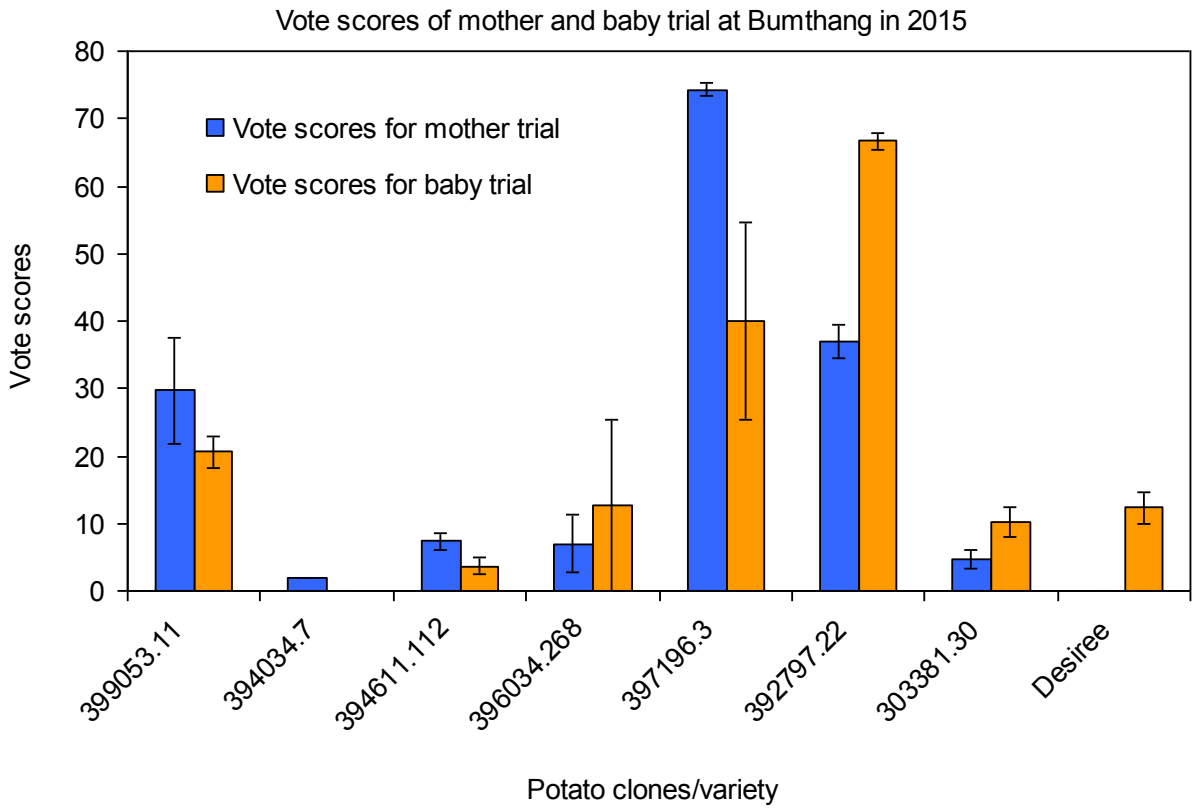

Figure 3. Farmers' preference vote scores of potato clones/variety for the mother and baby trial at Bumthang. Values are means of three replicates and error bars show standard errors of the means

Table 3. Summarized results of the least significant difference (LSD) method for yield comparisons amongst the clones/variety and chi-square analysis for the preference votes

Sl.No.	Clones/variety	Marketable yield in mother plot		Chi-square analysis of mother plot	
		Mean marketable yield (kg/ha)	Multiple comparison using LSD	Mean votes scored (No.)	Multiple comparison
1	399053.11	20,714	bcd	29.67	a
2	394034.7	11,905	e	2.00	cd
3	394611.112	27,202	ab	7.33	b
4	396034.268	14,524	de	7.00	bc
5	397196.3	32,262	a	74.33	a
6	392797.22	24,821	bc	37.00	a
7	303381.30	19,286	a	4.67	bc
8	Desiree	9,940	e	0.00	d
		Non-marketable yield in mother plot		Chi-square analysis of baby plot	
1	399053.11	4,048	a	20.67	ab
2	394034.7	655	c	0.00	d
3	394611.112	2,619	b	3.67	cd
4	396034.268	1,667	bc	12.67	cd
5	397196.3	1,726	bc	40.00	ab
6	392797.22	1,667	bc	66.67	ab
7	303381.30	1,012	c	10.22	cd
8	Desiree	2,381	b	12.33	bc

Values are means of three replicates in both mother and baby trials. Different letters indicate significant differences between the clones/variety at $P<0.05$.

3.1. Experiences from demonstration of new potato varieties

In order transfer the technology generated by the National Potato Program to farming community and to encourage farmers to grow for new varieties, a number of demonstration trials for new potato varieties (i.e. Nasephey Kewa Kaap [NKK] and Yusi Maap) was conducted in three potato growing Dzongkhags of Chukha, Haa and Wangdue (Table 4). The results of the demonstration trials show that both NKK and Yusi Maap had much better yield than the currently popular variety Desiree. Highest yield of NKK and Yusi Maap was observed in Chukkha with 37.1 and 35.5 ton/ha, respectively (Table 4). Yusi Maap was the top yielder in Chukha and Haa but NKK performed better in Wangdue. As expected, Desiree yielded the least among the three varieties in all the three locations and this could be attributed to decline in its seed quality. Analysis on the farmers' preference ranking showed that Yusi Maap was most preferred in all the three locations probably due to its red coloured skin (Roder et al 2008) and better crop productivity (Table 4). Preference for red skin by farmers can be further substantiated as Desiree, a low yielding variety, received the second

highest votes in Chukha and Haa based on its skin colour. The average yield of Yusi Maap was quite comparable to that of the average yield in the neighbouring countries (Bangladesh - 19.4, India-22.9 and Nepal-13.7 ton/ha (FAO, 2014). Unlike Yusi Maap (21.8-37.1 ton/ha), NKK showed larger yield variations (15.5-35.5 ton/ha) among the demonstration sites. On the whole, the study results indicate that new variety such as Yusi Maap has a great potential to increase potato production in the country. It is also highly likely that growers will go for it due to its red skin for better marketing preferences. On the contrary, white skinned potatoes are not as popular as their counterparts and therefore, future research efforts should be focused on releasing more red-skinned potato varieties.

Table 4. Summary of potato yields and farmers' preference ranking in three Dzongkhags: Results of technology transfer through demonstrations in 2017

Location	Genotype identification	Year of release	Variety name	Mean yield (ton/ha), n=3	SE of yield	Votes count (women)	Votes count (men)	Total votes	Rank
Lobnekha, Chapcha, Chukha	CIP393077.159	2014	NKK	**35.5**	2.53	18	19	37	**3rd**
	CIP392797.22	2017	Yusi Maap	**37.1**	2.58	43	41	84	**1st**
	CIP800048	1988	Desiree	**20.8**	1.35	23	24	47	**2nd**
Esu, Haa	CIP393077.159	2014	NKK	**15.5**	2.31	11	12	23	**3rd**
	CIP392797.22	2017	Yusi Maap	**23.4**	3.12	24	23	47	**1st**
	CIP800048	1988	Desiree	**13.7**	1.74	13	19	32	**2nd**
Baylanda Kazhi,	CIP393077.159	2014	NKK	**26.9**	0.99	57	36	93	**2nd**
	CIP392797.22	2017	Yusi Maap	**21.8**	4.42	81	43	124	**1st**
	CIP800048	1988	Desiree	**5.6**	0.87	30	17	47	**3rd**

NKK=Nasephey Kewa Kaap, SE = standard errors

4. Conclusions

Participatory varietal selection involves both scientific measurements and social evaluations; hence it has emerged as the best method to identify farmers' preferred crop varieties and their popularization. PVS helps farmers to get familiar with adoption of new varieties and helps researchers in decision making. Analysis on the farmers' preference ranking showed that 392797.22 (Yusi Maap) was the one of the preferred clone due to its high yield potential, red-coloured skin and it was also found be one of the better yielder. However, other genotypes of 399053.11, 394611.112, 397196.3 and 392797.22 are still better than the local varieties. Yusi Maap was released as an official variety because of its yield potential, late blight resistance (moderate) and micro-nutrient content besides farmers' preference for it. As such, there is a good scope to increase potato production in the country if these new varieties can be grown at large scale. In summary, the study results indicate that new variety such as Yusi Maap has a great potential to increase potato production in the country. It is also highly likely that

growers will go for it due to its red skin for better marketing preferences and due to its high micro-nutrient content for higher consumption. Contrastingly, white skinned varieties are not as popular as their counterparts and therefore, future research efforts should be focused on releasing more red-skinned potato varieties. The study has demonstrated farmers' preference for the new varieties and thus more resources should be invested to produce sufficient seeds of these promising new varieties. If the technology is disseminated and adopted well, the impact of the study could be realized in future as more income to the farmers and better health to the consumers.

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Effects of different planting methods on rice (*Oryza sativa* L.) crop performance and cost of production

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ABSTRACT

A field experiment was conducted at ARDC-Samtenling research station in 2017 to study the performance of rice using different rice planting methods. Four planting methods, namely line transplanting, random transplanting, drum seeding and broadcasting were applied on rice variety, Bhur Kambja-I that is currently considered as the best improved variety released for the low altitude rice agro-ecosystem. Rice cultivation in general and transplanted rice in particular is beset with issues of farm labor shortage and high cost of production in Bhutan. The results of the experiment showed that the planting methods did not have any significant effects on the grain yield and yield components. Grain yields for the different planting methods ranged between 3.10 ton/ha to 4.03 ton/ha. There was also no effect on yield components such as number of productive tillers and filled grains per panicle. However, the planting methods had significant effect on the crop maturity duration by about two weeks. Direct seeded rice matured early (113 days) while transplanting took 123 days. Further, direct seeding using either drum seeder or broadcasting had comparative advantage over transplanted rice in terms of labor requirement and cost of production. The cost advantage was found to be as high as 53% for drum seeding and 42% for broadcasting methods compared against line transplanting method. Based on the study, direct seeded rice could be promoted since it showed potential for promotion.

Keywords: *Agro-ecosystem***;** *Crop performance; Grain yield; Planting methods*

1. Introduction

Rice is the staple food for Asia (IRRI 2012) and is also considered as the most important crop for Bhutan. It is the most preferred staple food in Bhutan and the country accords top priority in increasing rice production for food security and rice self-sufficiency. However, Bhutan imports more than 50% of its rice requirement, mostly from India (Chhogyel et al 2015a). The country's production stands at 85,261 ton of rough rice (DoA 2015) while the import rose to 83,640 ton in the same year (PPD 2016). This situation has posed a huge challenge for the Department of Agriculture (DoA) to enhance rice self-sufficiency of 65% by the end of 12 Five Year Plan (FYP) in 2023. Globally, rice is largely grown in irrigated and rain-fed environments either through planting in puddle fields or direct seeded in both wet and dry conditions (GRiSP 2013).

While transplanting is the most common method of production, direct seeding is reported to be picking up worldwide. In Bhutan, farmers transplant rice in terraced fields wherein seedlings are randomly transplanted. The disadvantages of this method are that the crop

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density is not uniform and intercultural operations are inconvenient. The time required for the transplanting, harvesting and other management practices such as weeding is much higher. A shift from traditionally practiced transplanting to direct seeding method of rice cultivation could be one of the solutions to reduce the cost of cultivation. Therefore, considering high labor and management costs, it will be an essential intervention that is required to make the rice cultivation practices attractive. As is reported by the International Rice Research Institute (IRRI) that direct seeding is a low-cost method of rice establishment technology (IRRI, 2006), tapping its advantages and subsequent adoption of the technology is critical when Bhutan is striving to achieve rice self-sufficiency goal.

Bhutan by virtue of its location in rugged Himalayas, opportunity for farm mechanization is limited. Thus, labor shortage is one of the main constraints in rice farming in the country. According to the Agriculture Statistics (DoA 2016), farm labor shortage accounted for 53% of the farming constraints. Reports and field experiences show that fallowing of land in Bhutan mainly results from labor shortages, although there is no scientific study done to establish the fact.

In order to overcome such problems, there is a need to intensify labor saving technologies and farm mechanization where possible. Among the technological options in rice farming, direct seeding has tremendous potential and could be promoted. In Bhutan, majority of rice is transplanted and direct seeding is not popular which could be mainly due to lack of proper scientific experimentation in our situation.

Akhgari and Kaviani (2011) defined direct seeding of rice (DSR) as the process of establishing a rice crop from seeds sown in the field rather than by transplanting rice (TPR) seedlings from the nursery. They reported that the DSR either through dribbling, broadcasting and drum seeding can help rice farming communities bring down the labor cost. The only challenge confronted from using this method is reported to be the weed pressure. But, if weeds are well managed, DSR gives comparable yield to transplanted rice. Johnkutty (2002), through long term experiment proved that direct seeding could be a potential substitute for transplanted rice if proper and weed management techniques were followed. Mann (2007) in Pakistan also obtained rice yield of 3.70 ton/ha in a weed free direct seeded rice trial. Similarly, there are many literatures and studies that mention potential of direct seeded rice (Johnkutty 2002, Manjunatha et al 2009 and Sanusan et al 2010).

While direct seeding could be a potential method of rice production in Bhutan, there is a dearth of information and research in the country. Therefore, in order to promote direct seeding as an alternative method of rice cultivation, a location specific research and data was required. For this, four methods of planting viz. line transplanting, random transplanting, and direct seeding through broadcasting and use of drum seeders were evaluated. The objectives were to compare grain yield from different methods of planting for promotion as technology and to assess comparative advantage of direct seeded rice over transplanted rice in terms of labor cost.

2. Materials and Methods

2.1. Experimental design and materials

The experiment was conducted using Randomized Complete Block Design (RCBD) with three replications at the research station of Agriculture Research and Development Centre, Samtenling, in Sarpang Dzongkhag, Southern Bhutan.

Each plot size measured 8 x 4 m^2 and the test variety used was Bhur Kambja-I. Seed of Bhur Kambja-I was pre-soaked for 24 hours and incubated for 36 hours prior to seeding. From the same pre-germinated seed, nursery for transplantation was raised under wet bed condition. The same pre-germinated seeds were also used for drum seeding and broadcasting. Twenty one days old seedlings were transplanted maintaining 20 x 20 cm plant to plant and row to row distance. A recommended dose of fertilizers at 70:40:30 NPK Kg/ha was applied. Half 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. All intercultural operations such as weed control and irrigation were applied as and when needed. Butachlor @ 1.5 a.i/ha was applied to control grasses and sedges in the initial stage of crop followed by one hand weeding after one month of planting in all the treatments. For labor cost comparison, total man days required from nursery raising till weed management for all the methods were recorded.

2.2. Data gathering

Data from the field were gathered following standard procedures (IRRI 2002) and care was taken to minimize error and bias. 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.

For planting and weeding time, a stop watch was used to record the timings and for yield analysis, a crop cut was conducted on an area measuring 3x2 m^2. Calculation of grain yield was done following the standard formula and grain yield adjusted to 14% moisture level as given below:

$$\text{Grain yield (ton/ha)} = \frac{Plot\ yield\ (kg) x\ MC\ adj\ x\ 10{,}000}{plot\ size\ x\ 1000}$$

$$\text{Where MC adj} = \frac{100-MC}{100-86}, \text{ and MC= grain moisture at harvest}$$

The research data were compiled in Microsoft excel spread sheet and were analyzed using statistical software 'STAT-8'. The data were subject to the analysis of variance (ANOVA) at *P 0.05* level of significance for the comparison of treatment means.

3. Results and discussion

3.1.Grain yield and its components

Comparison among the different planting methods of planting rice showed that there was no significant difference in grain yield (*P*>F = 0.2258) and its yield components (Table 1). Grain yield varied between 3.10-4.03 ton/ha for the different treatments. Similarly, the number of productive tillers and number of filled grains varied between 9 to 12 and 165 to 177, respectively for different planting methods. The panicle length, however, showed significant difference (P>F = 0.00029) among the planting methods. Transplanted rice (line and random planting) gave the maximum length of panicles among the treatments.

Table 1. Effect of different planting methods on grain yield (ton/ha) and its components

Treatments	Grain yield (ton/ha)	Productive tillers/hill	No. of filled grains/panicle	Panicle length (cm)
Drum seeding	3.10a	12.00a	177.00a	22.00a
Broadcasting	3.92a	9.00a	172.00a	22.67bc
Random planting	3.90a	10.00a	165.00a	23.33ab
Line planting	4.03a	12.00a	168.00a	24.00a
P value	0.2258	0.1716	0.8978	0.0029
CV	14.31	14.32	11.64	1.62

3.2. Plant height

The plant height ranged between 117 cm to 120.33 cm among the different planting methods (Figure 2). The two transplanting methods (line and random) resulted in taller plants as compared to direct seeding using drum seeder and manual broadcasting. Mean plant heights in both broadcasting and drum seeding were 117 cm while the plant heights in random transplanting and line planting were 120 and 120.33 cm, respectively.

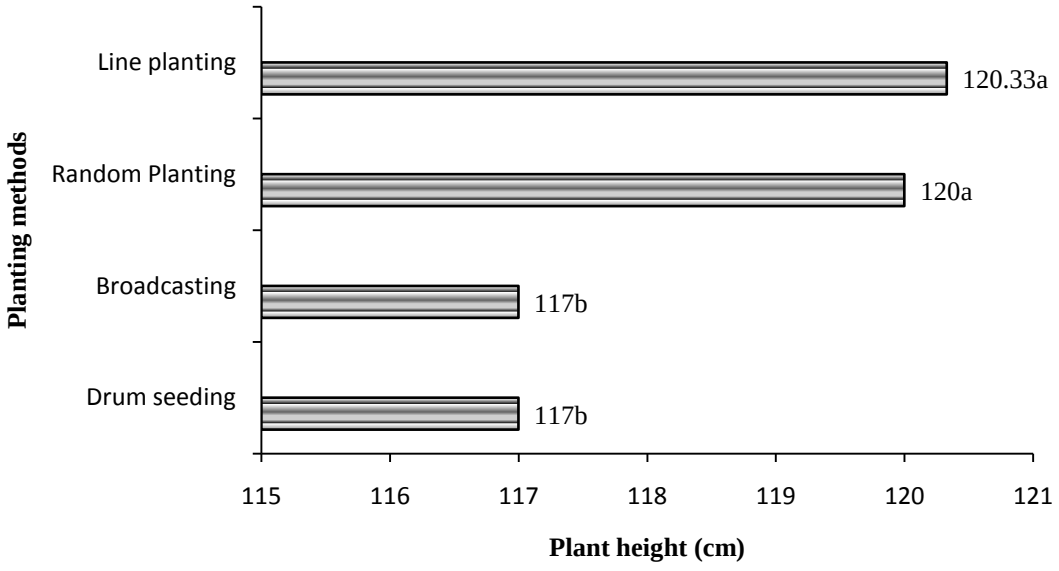

Figure 1. Plant height of rice as affected by different planting methods

3.3. Maturity duration

The test variety Bhur Kambja-I showed significant difference in days to maturity (DTM) using different planting methods. It took 127 days to mature in two transplanted plots while it took only 113 and 114 days in drum seeding and broadcasting, respectively (Figure 3). This difference could have been due to environmental shock imposed from uprooting of the seedlings until crop establishment for the transplanted rice. Overall, the direct seeded and the transplanted rice differed by about two weeks and drum seeded rice took the shortest number of days to mature at 113 days.

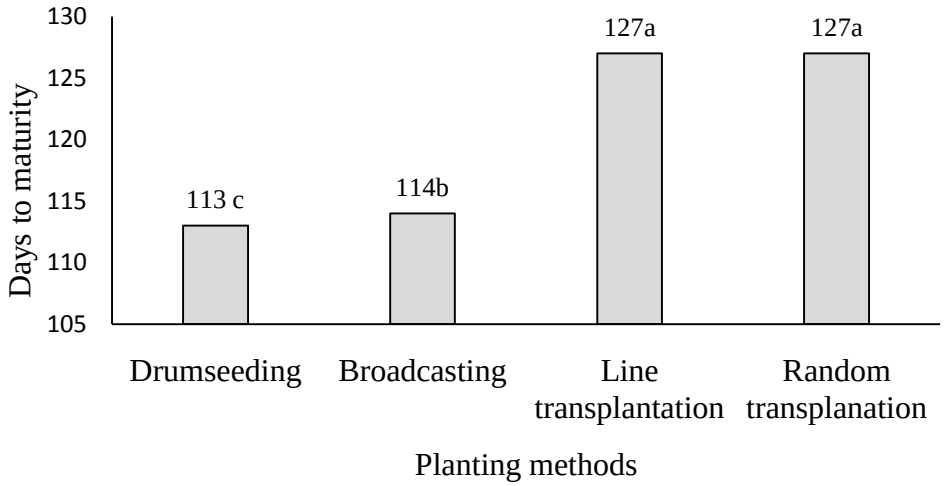

Figure 2. Days to crop maturity as affected by different planting method

3.4. Labor requirement and costs per Acre

The management practices other than seedling preparation and transplanting remain same for all methods. Practices such as seedling thinning and weeding were also taken into account for the cost comparison. In terms of labor requirement, the study showed that there is comparative advantage in direct seeded rice over transplanted rice. The direct seeding method drastically reduced labor requirement from 33 man days in line transplanting and from 29 man days in random transplanting to 15.5 and 19 man days in drum and broadcasting methods of planting, respectively (Table 2). There was higher cost of labor in transplanted rice as compared to the direct seeded rice. The cost of labor for line transplanting was Nu. 11,550/acre while it was Nu. 10,150/acre for random transplanting. Conversely, the labor cost for drum seeding and broadcasted methods were just Nu. 5,425/acre and Nu. 6,737/acre, respectively. Therefore, there is a cost advantage of 12% for random transplanting, 53% for drum seeding and 42% for broadcasting against the line transplanting method.

Table 2. Man-days requirement and cost of labor for different planting methods per acre

Cultivation practices	Different planting methods			
	Line transplanting	Random Transplanting	Drum Seeding	Broadcasting
Nursery development (Man-days)	3	3	0	0
Seedling uprooting (Man-days)	1	1	0	0
Field preparation (Man-days)	3	3	3	3
Transplanting (Man-days)	16	10	0.5	0.25
Seedling thinning (Man-days)	0	0	0	2
Weeding (Man-days)	10	12	12	14
Total labor required (Man-days)	33	29	15.5	19.25
Labor cost (Nu/head)	350	350	350	350
Total costs (Nu)	11,550	10,150	5,425	6,737.50
Percent cost advantage against land transplanting		12%	53%	42%

4. Discussion

4.1. Grain yield and its components

Though the planting methods did not show significant difference in grain yields, line transplanting produced the highest yield of 4.03 ton/ha followed by random transplanting at 3.92 ton/ha and broadcasting at 3.90 ton/ha. Insignificant difference in yield components such as number of productive tillers and number of filled grains per panicle further indicated that planting methods do not affect yield performance of rice. If management practices are applied correctly, a crop of rice could be produced using any methods of planting. This is in agreement with the research conducted by Rana et al (2014) in Bangladesh involving short duration Aman rice. Kumar and Ladha (2011) also reported that rice yields in transplanted and direct seeded rice were almost the same. Insignificant differences in other yield attributes among the different methods of planting further revealed that all methods have potential for sustainable rice production by skipping nursery to transplanting activities. Although not significant, the findings on the highest number of grains per panicle in drum (177) and broadcasted (172) method from this experiment agrees with the finding of Rana et al (2014) and Akhgari et al (2013). Thus, the germinated seeds when sown directly perform well and were comparable to transplanted rice which normally produces higher number of productive tillers. Higher number of productive tillers in transplanted rice could be due to proper spacing and uniformity which is not the case in direct seeded rice. In transplanted rice, there is no overcrowding of seedlings and less weed pressure, thus leading to higher number of tillers. Singh et al (2008) reported that lower number of tillers in direct seeded rice is attributed to higher level of weed pressure as compared to transplanted rice. In all the parameters, the coefficients of variations (CV) were within 15 which are normal for agricultural experiments.

4.2. Plant height

The difference in plant height (cm) among the different planting methods could be attributed to increased crop competition in both direct seeded methods (broadcasting and drum seeding). Taller plants in transplanted rice (120 cm and 120.33 cm) could be due to deeper rooting system as seedlings were firmly planted into the puddled soil. However, in direct drum seeding and broadcasting methods, seeds were sown at the surface thus leading to reduced rooting system. Research by Naresh et al (2013) on direct seeded and transplanting methods by Naresh et al (2013) showed that plants were taller in transplanted rice as compared to direct seeded method.

Plant height in rice is an important agronomic trait and has tremendous effect on the yield potential of the crop. Moreover, it has marked influence over the varietal choice in Bhutan since rice straw is used as off-season cattle feed in winter besides the grain yield. Bhutanese farmers prefer varieties that produce good yield and also more straw for their cattle (Chhogyel et al 2015b). In modern rice variety development, plant height is one of the breeding objectives (De Datta 1981) where rice varieties of shorter height with sturdier culm carrying heavier panicle heads that do not lodge are preferred.

4.3. Maturity duration

The difference in days to maturity among the various methods of planting could be due various factors such as rooting depth, nutrition, weed pressure and inter-crop competition. Longer maturity days for transplanted rice in both random and line planting could be attributed to transplanting shock and recovery. In transplanted rice, the seedlings were uprooted and re-planted thereby directly exposing them to physical stress which requires a week or two to recover and perform normal physiological functions. In direct seeded rice, the seedlings were not disturbed and hence took just 113-114 days to mature. The crop in direct seeded rice establishes earlier as compared to transplanted rice, thus leading to faster physiological maturity since there is no transplantation injury. Overall, the plants showed a difference of 14 days to mature. Similar findings were reported in the review works of Farooq et al (2006a, b; Farooq 2010). It has also been reported that rice matures about 7-10 days earlier and have less methane emissions (Balasubramanian and Hills 2002). Thus, the direct seeded paddy may be harvested early thereby giving time for the following crop.

Crop maturity duration is one of the most important agronomic parameters in all rice ecosystems. For Bhutan, maturity duration is more important since the crop has to fit within a single growing period. Crop growing period in Bhutan's condition is short and therefore has to time it properly to optimize yield potential. Normally, the people prefer medium crop maturity group of 130-160 days for normal season (Chhogyel et al 2013).

4.4. Labor requirement and costs

For the labor requirement and costing analysis, the main field operations until weeding was considered since rest of the practices would involve more or less same labor. The field operations considered for the current study included nursery development, seeding preparation, field preparation (bund plastering and puddling), planting and weeding Among the different methods of planting, line planting required the highest number of labor at 33

man-days followed by random planting at 29 man-days due to additional man power required for nursery, and transplanting operations. In case of direct seeded rice using drum and broadcasting methods, there was no nursery development and thus, no transplanting of seedlings was required. Thus, direct seeding showed drastic reduction in labor requirement. However, direct seeding method specially the broadcasting method showed additional labor requirement for seedling thinning and weeding operation. Overall, transplanting method had higher labor requirement. While there are no literatures or studies on direct seeded rice in Bhutan, studies in other countries have shown that direct seeded rice has a comparative advantage over transplanted rice mainly due to reduction in labor cost (Farooq et al 2010, Gill et al 2014). This led to labor cost difference of Nu. 4,000-6,000 per acre between the transplanted and direct seeded rice. There was also a slight difference in labor cost between line planting and random planting due to additional labor required for guiding with ropes during transplanting. The cost advantage of direct seeding was as high as 53% for drum seeding and 42% for broadcasting method. Gill et al (2014) also reported that direct seeding reduced cost of production by about 9%. Study by Naresh et al (2013) in India also showed that direct seeded rice is more economical than transplanted rice. Further benefit cost ratio of 1.11 was obtained by Yanous et al (2016) who made an economic comparison between direct seeded and transplanted rice involving super basmati rice in Pakistan. This shows that direct seeding method of planting is one potential method of rice production requiring less labor.

5. Conclusion

Based on the findings from on-station research at ARDC, Samtenling (Sarpang), direct seeded rice is a potential method of production for promotion in the country. The crop performance in terms of grain yield and its components including basic agronomic parameters showed that direct seeding method, either through drum seeding or broadcasting is comparable to transplanted rice. The grain yield from different methods of planting ranged between 3.10 ton/ha to 4.03 ton/ha without showing any significant difference. Similarly, there was no difference in yield components, thus, indicating that direct seeding does not reduce grain yield as perceived by many farmers in the country. Based on number of labor required for different cultivation practices, direct seeding was found to be better since it required less labor compared to transplanting. This contributed to reduction in labor cost, thus enhancing profitability of rice farming through direct seeding. Direct seeded rice required just 15 and 19 man-days for the two methods of direct seeding as against 33 and 29 man-days in transplanted rice. Therefore, there is additional cost difference of Nu. 4,000 to 6,000 in transplanted rice. The overall results indicate that the labor intensive and costly method of transplanting could be substituted by direct-seeding without compromising productivity. The research proved that direct seeded rice is worth promoting in the southern rice agro-ecosystem as one of the strategies to overcome labor shortage in rice farming.

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Potato mini-tuber production using an Aeroponics System during winter

Ngawang[i] and Thubten Sonam[j]

ABSTRACT

This study evaluated the performance of potato mini-tuber production using aeroponics technology during winter at National Seed Centre, Paro. Three potato cultivars: Khangma Kaap (KK), Nasephey Kewa Kaap (NKK) and Yusi Kaap (YK) were evaluated in an aeroponics at two different planting times (November and December) using a split-plot design with three replications. The combined analysis, i.e., General Linear Model-Univariate was performed to test the interaction between planting times and cultivars. The interaction between planting time and cultivars showed no significant difference for any of the plant growth and yield variables. Further, planting time did not influence minituber production for the measured traits of plant height, no. of leaves, root length, number of minituber and minituber weight. However, the main effect of cultivar was highly significant ($p < .01$) for growth, yield and plant mortality rate. NKK yielded highest (18.39g/plant) in terms of weight followed by KK (9.22g/plant) and YK (8.30g/plant). Plants in NKK cultivar also had the maximum (8) numbers of mini-tuber per plant than KK (5) and YK (3). Maximum (39%) plants mortality was observed in YK compared to the lowest, NKK (16%). This result shows that NKK has better adaptation and is more productive under winter growing conditions than other two varieties. Thus NKK may be recommended cultivar among the three for mini-tuber production through aeroponics during winter. Since, the plants response under aeroponics conditions was cultivar dependent and not planting time dependent, further testing is recommended to select more adaptive cultivars for winter season.

Keywords: *Aeroponics; cultivars; planting time; potato mini-tubers; winter*

1. Introduction

Potato (*Solanum tuberosum* L) is one of the most important cash crops for farmers in Bhutan. According to the Bhutan Trade Statistic (2014), potato ranked first in terms of volume of agriculture trade and was in the top 10 export major commodities, worth Nu 688.79 million. However, there are a number of production problems in potato. Limited accessibility to high quality potato seed is a perennial problem amongst many growers in Bhutan. The annual seed potato requirement for Bhutan is approximately 10,000 ton and almost 99% of the requirement is covered through seed sources from informal system (Chettri et al 2006). In the absence of reliable sources of quality seed, many growers opt to use their own farm-saved seeds or source from the local market. Such practices contribute towards sub-optimal yields due to seed degeneration caused by viruses and others potato diseases (Roder et al 2008; Gildemacher et al 2009). To make seed potatoes available and minimize the problem of seed potato degeneration, the need of rapid multiplication has become a priority.

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In 2012, aeroponics system of potato mini-tuber production was introduced at the National Seed Centre (NSC), Paro in collaboration with the National Potato Program (NPP). It is a plant culture technique in which mechanically supported plant roots are intermittently misted with nutrient solution (Barak et al 1996). The plants are grown in air without the use of soil medium. This system has potential to produce disease free planting materials with high multiplication rate. The technique is called 3G (three generations) seed strategy (Otazu, 2010), that can lower costs and multiply seed within the three generations compared to conventional methods, which takes five to six generation. In Peru, an individual potato plant can produce over 100 mini-tubers (Otazu 2010). This contrasts with conventional methods that produce only about 5–6 tubers per plant (Hussey and Stacey, 1981; CIP 2008).

Aeroponics in Bhutan is first of its kind in South Asia (Wangchuk 2012) and the facility regarding its full potential was not explored. According to Ritter et al (2001) and Mbiyu et al (2012) potato mini-tubers can be produced twice a year using aeroponics technique. However, the facility in NSC, Paro was operated once a year (April to October) only. Therefore, this study was designed to test the feasibility of growing potato plants during winter, so that more quantity of potato mini-tubers can be produced in a year. In order to test the feasibility of winter production, two planting times (November and December) were used, because different planting time influences the performance of plants under aeroponics system (Yan et al 2000; Mateus-Rodriguez et al 2014). Similarly, three cultivars (Khangma Kaap, Nasephey Kewa Kaap and Yusikaap) were included, as many studies have found the difference in plant performance among the cultivars under aeroponics (Farran et al 2006; Otazu 2010). Therefore, the present study was conducted with the objectives to evaluate the effect of planting time and cultivars for potato mini-tuber production in winter using aeroponics technology.

2. Materials and Method

2.1. Location of the experiment

The experiment was conducted under aeroponics greenhouse (AGH) conditions in the National Seed Centre (NSC), Paro. It is located at an altitude of 2,406 meter above the sea level between 27º 22’59” N and 89º 25’12” E. The AGH dimension was 34 m long, 9 m wide and 4 m high. The duration of the study was five months (November 2015 to March 2016).

The experiments followed split-plot in a Randomized Complete Block Design (RCBD) with planting times (November and December) in main-plots and varieties (Khangma Kaap, Nasephey Kewa Kaap, and Yusi Kaap) in sub-plots with three replications. A distance of 10 cm between the plants and 15 cm between rows were maintained. Each cultivar had 180 plants and in total, there were 540 plants. The temperature inside the AGH was recorded hourly using HOBO data logger (model: UX 100 - 003 series).

2.2. Planting procedures and data collection

The one month old *in-vitro* potato plantlets produced from tissue culture laboratory were hardened and rooted in the screen-house before transplanting into the aeroponics unit. After 30 days, the plants were transplanted into the aeroponics. The first planting was done on 1st

November 2015 and the second in 1st December 2015. The plants were planted into holes on the styrofoam lid at the crown with roots hanging inside the box. The roots were fully exposed to the nutrient fog inside the growth chamber. The potato nutrient solution of Sichuan Academy of Agriculture Science, China was used. The nutrients were dissolved in distilled water and then poured into the nutrient tank. A 1000 L tank was used to store the nutrient solution for circulation and 0.75 HP constant pressures pump to distribute the nutrient solution through pipe. The solution was compressed through the nebulizers by a high pressure pump, forming a fine mist in the growth chambers, and which was sprayed onto the hanging potato roots. The plant roots received the nutrients from the nutrient mist and grew. The nutrient solutions were collected at the bottom of the growth chamber and flew back into the tank. This was re-used for 14 days, there after a fresh stock was added.

A simple random sampling method was used to select the sample plant for data collection. The sample numbers were determined by using Yamane (1967) formula with ± 5% precision level. The data were recorded from 12 tagged plants (N = 30) per plot at an interval of 15 days between each measurement (30, 45, 60, and 75 days after transplanting). Data on vegetative growth, yield and plant mortality rate were recorded. Plant height was measured with a calibrated ruler from the base of styrofoam to the plant apex. Average plant height per plant was calculated. Number of leaves per plant was recorded and articulated in numbers. Root length was measured from the stem suspended inside growth chamber to the tip. The percentage of plant mortality at harvest was determined. The total numbers of mini-tubers from 12 plant samples were harvested and mean per plant were calculated. The mini-tubers were categorized into two categories (i.e. normal weight > 8 g and underweight < 8 g) according to CIP evaluation (Otazu 2010). These grades were counted and weighed separately using digital weighing balance. The weight and number of mini-tubers were calculated for each treatment. The unit was recorded into weight (g per plants) and percent of mini-tubers under normal weight and underweight category. The average number of mini-tuber per plant was converted into number of mini-tuber per 4000 plants (the present capacity of AGH 306 m^2) for economic analysis.

2.3. Mean day and night temperature inside AGH

Plant growth rate and tuberization is influenced by day net photosynthesis and dark reaction (Leach et al 1982). Therefore, the day and night time temperature during the experimental period was assessed. The highest mean night and day time temperature was recorded in March (11.94 $^{\circ}$C and 23.20 $^{\circ}$C) and lowest (6.26 $^{\circ}$C and 13. 81 $^{\circ}$C) in January during the experiment periods (Figure 1). The three months (December, January and February) have relatively low temperature both for night and day (Figure 1), compared to recommended temperature (10 $^{\circ}$C to 15 $^{\circ}$C and 18 $^{\circ}$C to 20 $^{\circ}$C) respectively, for potato development and tuberization (Vandam et al 1996; Levy and Veilleux 2007; Otazu 2010). In case of two planting times (November and December), there was difference of 3 $^{\circ}$C and 4 $^{\circ}$C in the mean night and day temperature respectively.

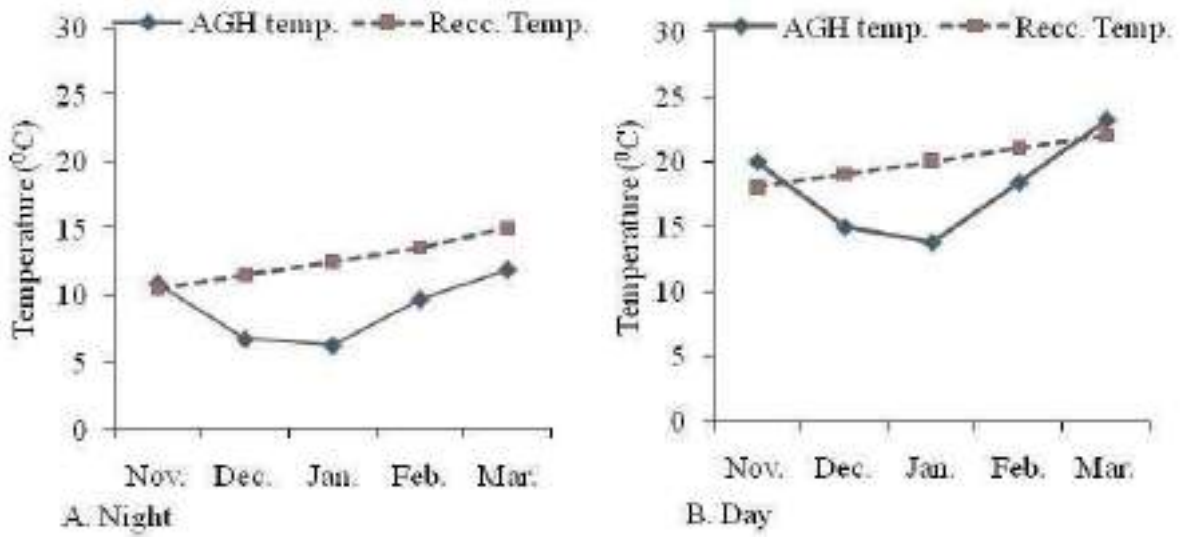

Figure 1. A. night and B. day, mean temperature inside Aeroponics Green House with recommended temperature

As per the SPSS guideline of Field (2009), the combined analysis (General Linear Model-Univariate) was performed to test the interaction between planting times and cultivars. Bonferroni multiple range test was used to test the level of significance among the means of the cultivars. Statistically the significant level was considered at $p = 0.05$.

3. Results and Discussions

3.1.Growth parameters

The combined analysis of variance showed highly ($p < 0.01$) significant differences between the three cultivars for plant height, number of leaves and root length (Table 1). However, the interaction effect of planting time and cultivars was not significant. The lack of interaction between planting time and cultivar effect was in contrast with the finding of Tshisola (2014); Farran et al (2006) that potato plant growth and number of leaves produced were subjective to environment and environment by genotype interaction. The insignificant effect of planting times in the present experiment could be due to the minimum temperature (3°C-4°C) difference between two planting time that did not permit strong competition between the plants. The early planting (October) need to be considered in future studies.

Table 1. Mean squares and significance levels from the combined ANOVA for plant growth

		Growth variables		
Source of variation	*df*	Plant height	No. of leaves	Root length
Planting time	1	5.89ns	7.45ns	6.57ns
Cultivars	2	440.96**	17718.71**	706.02**
Planting time * cultivar	2	2.35ns	0.813ns	0.23ns
Error	66	0.88	69.95	13.73

**Highly significant difference at $P < 0.01$; *df* = degree of freedom; ns = not significant

3.1.1. Effect of cultivars on plant height

Multiple comparison using Bonferroni test indicated that Nasephey Kewa Kaap showed tallest plant height (16.11 cm) compared to the lowest, Yusikaap (8.56 cm) at 75 days after transplanting (Figure 2). YK generally showed retarded growth throughout season under the aeroponics condition, however, there was no significance between the YK and KK. The highly significant difference among the cultivar for plant height might be attributed by genotypic differences. NKK responded positive under aeroponics condition than KK and YK. This result is in inline with the findings of Farran et al (2006) that the potato cultivar Zorba responded with higher vegetative cycle and plant height compared to other local cultivar under aeroponics system in Spain. Further, In Rwanda, potato cultivar Kinigi showed superior growth rate when compared to Kigega cultivars (Masengesho et al 2012). Farran et al (2006) stated that the inhibition (poor growth) was because of its weak capacity for utilizing the low light intensity in the aeroponics greenhouse. Therefore, this result indicates that plant height response to aeroponics system was cultivar dependent.

3.1.2. Effect of cultivars on number of leaves

The maximum numbers of leaves per plant were recorded in NKK plants (13, 29, 44, and 79) and the minimum in YK (7, 13, 18, and 32) at all the four consecutive measurements (Table 2). The significance difference due to cultivar was in an agreement with Otazu (2010) and Masengesho et al (2012) that the potato vegetative development inside an aeroponics is genotype dependent. Similarly, the study conducted in Iran by Movahedi et al (2012) reported that the Marfona cultivar had the highest numbers of leaves and root length compared to local cultivar, Agria and Savalan under aeroponics condition. Hence, the positive response of NKK might have triggered more number of leaves per plant. The least numbers of leaves in KK and YK might be attributed to poor growth under aeroponics system.

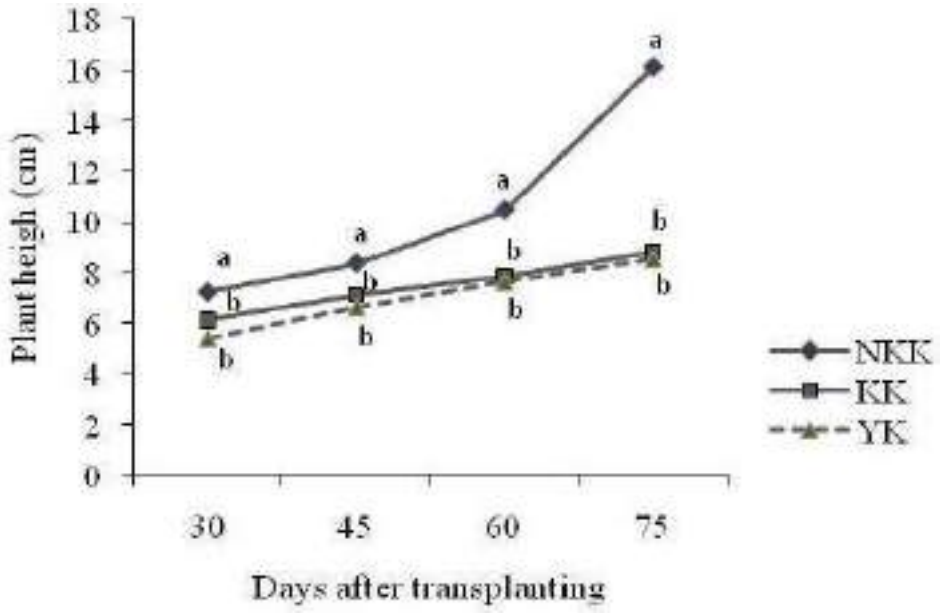

Figure 2. Effect of cultivar on plant height

Different letter (s) within DAT, indicates significant difference at $p < .01$ level

Table 2. Effect of cultivar on numbers of leaves per plant

Cultivars	Days after transplanting			
	30	45	60	75
KK	7[b]	12[b]	19[b]	32[b]
NKK	13[a]	29[a]	44[a]	79[a]
YK	7[b]	13[b]	18[b]	32[b]
F-value	**	**	**	**

** Highly significant difference at $P < 0.01$; different letter in column indicate significant difference

3.1.3. Effect of cultivars (cv) on number of root length

The mean root length showed high significant difference ($p < 0.01$) among the cultivars. The highest root length per plant was recorded in NKK (17.07 cm, 19.09 cm, 26.04 cm and 31.30 cm) and the lowest, YK (11.65 cm, 15.86 cm, 17.44 cm, and 21.34 cm) at all the measurements (Table 3). Conversely, there were no significant differences between KK and YK. As discussed earlier, the variation of root length was cultivar dependent and NKK being the tallest plant and with maximum numbers of leaves might have influenced better root development. According to Crist and Stout (1929), there is a persistent tendency towards a positive correlation between shoots, leaves and roots. The intensive studies in wheat plant showed that plants exhibited marked specific and varietal differences with respect to relative development of roots when grown under the same environmental conditions (Weaver et al 1924). The present study shows that the maintenance of a proper balance between root and shoot seems to be of great importance as reported by Weaver and Himmel (1929) that "if either is too limited or too great in extent, the other will not thrive".

Table 3. Effect of cultivars on root length (cm)

Cultivars	Days after transplanting			
	30	45	60	75
KK	12.19[b]	16.27[b]	18.62[b]	22.60[b]
NKK	17.07[a]	19.09[a]	26.04[a]	31.30[a]
YK	11.65[b]	15.86[b]	17.44[b]	21.34[b]
F-value	**	**	**	**

** Highly significant difference at $P < 0.01$; different letter indicates high significant difference

3.2. Effect of planting time on plant survival

The records on plant survival of November and December planting were compared. The test showed statistically no significant difference between November and December timing, however, in absolute mean value, November planting time had the maximum (74%), $n = 270$, survival rate than December (68%), $n = 270$. The maximum survival rate could be due to

higher night temperature (5°C) at the time of transplantation in November that favored the plant survival. Conversely, the lowest night time temperature (0.53°C) in December might have caused more injury to plants causing death. According to Patsalos (2005), at temperature of 3°C, serious damage is caused to the foliage and at temperature below minus 2 °C; plants freeze entirely and die.

3.3. Effect of cultivars on plant mortality

There were significant difference among the cv on plant mortality $F(2,3) = 13.73$, $p = .031$. The highest plant mortalities rate was recorded in YK (39%) and the lowest (16%) in NKK (Figure 3). However, the mortality rate of KK was not significantly different from both the highest and lowest rates. The highest rate of plant mortality could be due to low night time temperature weakening subsequent vegetative growth. Levitt (2005) reported that chilling injury results when plants are exposed at 0°C to 8°C for more than three hours. The rate of chilling (low night temperature) combined with weak plants could possibly have caused plant mortality. In contrast, the rate of low mortality could be due to sturdy plant growth and genotypic vigor. The cultivar with relatively long maturity periods grows better where temperature is a limiting factor (Mateus-Rodriguez et al 2014) such as in Peru, Huancayo (3,259 m.a.s.l.), chucmarina cv had shown low mortality compared to other CIP cv. Similarly, the late maturity cv, NKK (145 – 160 days) (DoA, 2015) had the highest number of survival rate than KK (100 – 120 days) and YK (100 – 120 days). This indicates that the rate of plant survival and mortality was also due to cv differences.

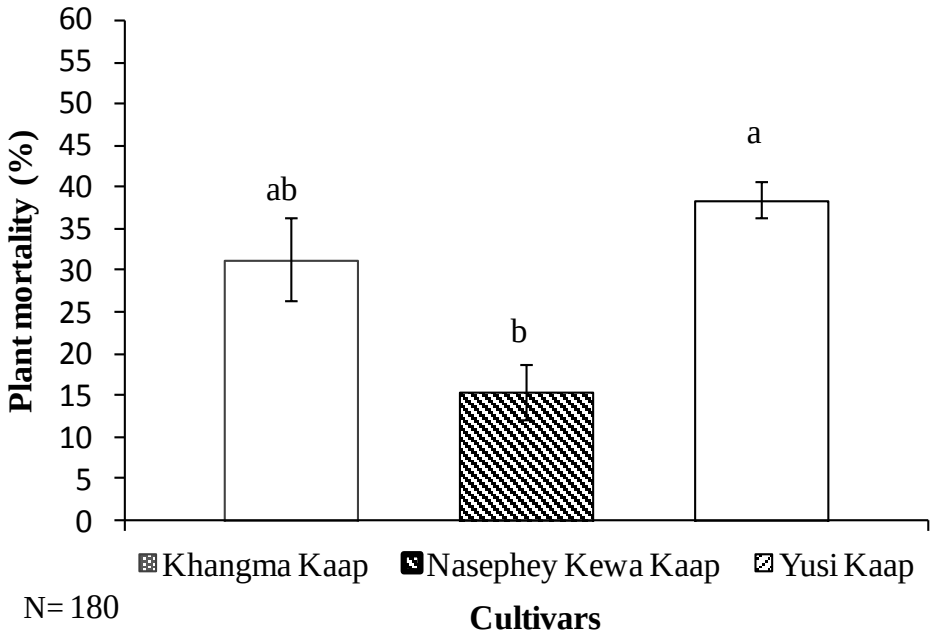

Figure 3. Percent of plant mortality

Different letter indicates significant difference at $p < 0.05$ level; Mean ± *SEM (standard error of mean)*

3.4. Yield parameters

3.4.1. Effect of planting time and cultivars on weight and number of mini-tubers per plant

The combined analysis of variance showed no significant differences due to effects of planting time and planting time by cultivars interaction in all the measurement of yield variables (Table 5). However, effect of cultivars showed highly significant difference ($p < .01$) for the four yield variables categories. This result indicates that the yield response under aeroponics was attributed by difference in cv traits and more testing of cv is recommended as explained by Otazu (2010).

Table 5. Combined ANOVA for the weight and number of mini-tuber per plant

Source of variation	*df*	Mean square			
		No. of mini-tuber per plant	No. of mini-tuber > 8 g	No. of mini-tuber < 8 g	Weight (g per plant)
Planting time	1	0.92ns	0.03ns	0.22ns	0.23ns
Cultivars	2	177.31**	3.16*	128.97**	747.78**
Planting time * cultivars	2	0.06ns	0.002ns	0.009ns	4.29ns
Error	66	1.32	0.18	1.78	5.26

*Significant difference at $p < .05$; ** highly significant at $p < .01$; ns = no significant difference

3.4.2. Yield and number of mini-tuber of three cultivars

The maximum yield (18.39 ± 0.213) gram per plant was recorded in NKK plot and the minimum (8.30 ± 0.564 g) from YK (Table. 6). The maximum yield recorded from NKK could be due to higher number of leaves and better plant growth. Similarly, Anand and Krishnappa (1988) reported that higher number of leaves and healthy crops yield high due to translocation of more photosynthates to tubers. The above result was in contrast with the finding of Tshoka et al (2012) that the low yields corresponded to an increase in above ground growth due to the competition for sucrose unloading between the storage organs (mini-tubers) and the above ground growth (leaves and stems). Such competition for assimilates controls aerial growth (leaves and stem) (Rykaczewska, 2004; Jackson, 1999). However, this study found that the maximum plant growth under aeroponics gave higher yield (grams per plant) compared to low vegetative growth.

Table 6. Effects of cultivars on yields

Cultivars	Yield (g per plant)	
	Mean	*SEM*
Khangma kaap	9.22[b]	0.21
Nasephey kewa kaap	18.39[a]	0.53
Yusikaap	8.30[b]	0.56
F value	**	

Different letter indicates significant difference at $p < .01$ level. ** Highly significant at $p < .01$

3.4.3. Number of mini-tuber per plant

NKK had significantly higher (8 ± 0.263) number of mini-tubers per plant compared to the lowest, YK (3 ± 0.212). Further, there was significant difference between YK and KK (5 ± 0.214) (Figure 4). The result indicates that cvs had a differential behavior for yield variables under aeroponics system. Similar to this study, Movahedi et al (2012) in Iran found one of the three varieties (Agria, Marfona and Savalan) performed better than the other two. Further, the study conducted in Rwanda by Masengesho et al (2012) and in Spain by Farran et al (2006) found that response in an aeroponics system is cv dependent and recommended to determine for each type. On the contrary, the study conducted in Hauncayo, Peru by Mateus-Rodriguez et al (2014) reported that yield variables were primarily influenced by genotype and environmental interaction. The more vegetative growth cv resulted in higher numbers of mini-tuber, as reported by Wolf et al (1990) that the increase in tuber number was due to increased photosynthetic activity and translocation of photosynthesis to the sink which have helped in the formation of more tubers.

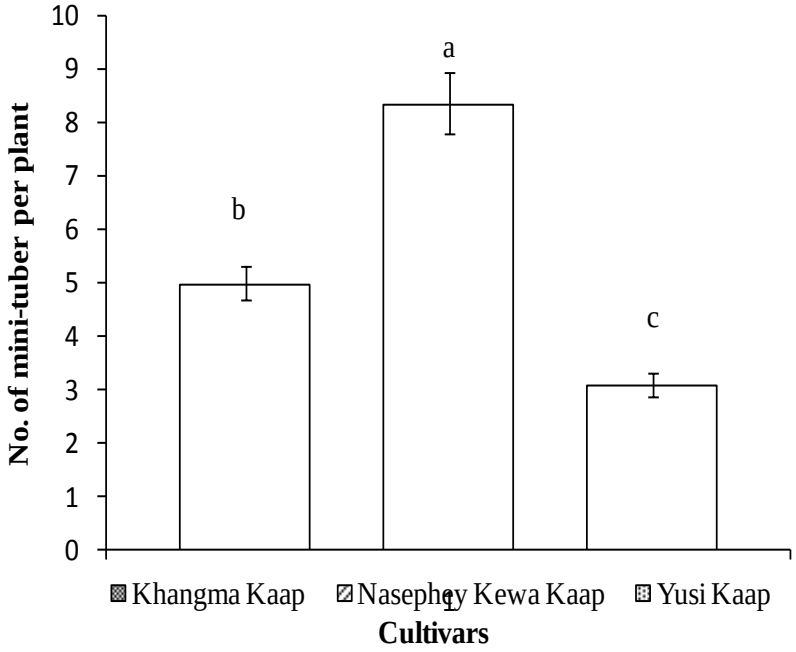

Figure 4**.** Effect of cultivars on numbers of mini-tubers per plant

Different letter indicates significant difference at $p < .01$; Mean ± *SEM*

4. Conclusion

There was no interaction due to effect of planting times and cultivars on plant growth and yield variables, but the main effect was due to cultivars. Planting time does not influence mini-tuber production for the measured traits of plant height, no. of leaves, root length, number of mini-tuber and weight. The cultivar effect was significant and Nasephey Kawa Kaap yielded highest both in terms of weight and no. of mini-tubers followed by Khangma Kaap and Yusi Kaap. NKK was found to be best performing and is recommended among the three cultivars for mini-tuber production through aeroponics. Since the response under aeroponics was cultivar dependent, further research is recommended to test more cultivars.

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Potential Impact of Climate Change on the Scope of Important Fruit Crops

Loday Phuntsho[k] and Lhap Dorji[k]

ABSTRACT

In Bhutan, Renewable Natural Resources Sector (Agriculture, Livestock and Forestry) provides livelihood for close to 57% of the total population and accounts for 16.8% of the total GDP, and Agriculture Sector alone contributes more than 10% to the total GDP. Hence, Agriculture in general and horticulture in particular has a critical role in the Nation's stride towards achieving self-reliance and sustainable development goals. Horticulture sector is recognized as one of the industries of the future given its potential for income generation and enhancing food and nutritional security. However, Agriculture sub-sector is buffeted by number of challenges and of particular interest is climate change since it is one of the sectors expected to bear the brunt of climate change. Climate in Bhutan is changing. Some studies show that over the last two and half a decade, temperature has risen by 0.3 to 0.5^{o}C and rainfall has become more erratic. Hence, the needs to study the potential impact of climate change on the scope of agricultural crops, particularly on economically important crops. In this study, impact of climate change on two most important fruit crops, apple and mandarin orange, was studied using FAO's EcoCrop Model in the year 2050 under two emission scenarios (RCP4.5 and RCP8.5). The result shows considerable change in the areas suitable for these two important horticultural fruit crops. Of the two, apple loses net suitability area under both the scenarios with maximum under RCP 8.5, whereas mandarin gains under both the scenarios with maximum under RCP 4.5. The study is expected to provide useful information regarding future adaption strategies.

Keywords: *Climate change; apple; mandarin orange; eco-crop model; suitability area*

1. Introduction

Renewable Natural Resources (RNR) Sector that comprises of Agriculture, Livestock and Forestry is the single largest sector that provides livelihood sources for close to 57% of population and contributes about 16.8% of the total GDP (MoLHR 2014). Agriculture sub-sector (field and horticultural crops) alone contributes more than 10% to the total GDP (NSB, 2016). Further, Horticulture is recognized as one of the important industries considering its potential for income generation and enhancing food and nutritional security (Planning Commission, 1999). In due course of time, the consumption of horticultural crops, especially fruits and vegetables, is expected to increase by about 47% as income doubles (Dukpa & Minten 2010). However, since agricultural activities are largely climate dependent, it is considered one of the most vulnerable sub-sectors to climate change (Solomon 2007). In Bhutan there are limited studies about climate change and its potential impact on agriculture. Few of the studies available have indicated that since 1985, temperature has risen by 0.3 to 0.5^{o}C and rainfall has become more erratic (Tse-ring 2010; Phuntsho & Dorji 2014), which suggest that there is a scope to study as to how such changes in climate parameters might

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affect crops, particularly economically important crops such as fruit crops.. Among others, one of the serious implications of climate change is the likely change or shift in agro-ecological zones for cultivation of any specific crop (Kurukulasuriya & Mendelsohn, 2008). This study thus assesses the potential impact of climate change on two most important fruit crops, Apple and Mandarin Orange, in terms of change or shift in areas suitable for cultivation, and corresponding economic implications. These crops arethe two most economically important fruit crops in Bhutan. In 2016, 6587 ton of apple and 42,700 ton of mandarin orange were produced earning Nu 215 million and Nu 432 million respectively (IMS 2016).

2. Materials and Method

Climate change studies require climate data for at least 30-year period (NOAA 2017). For the current study, data were extracted from WorldClim database. It provides average climate data from 1950 to 2000 (R. J. Hijman 2005). For future climate data, ensemble of three (BCC_CSM1.1, INM_CM$ and NIMR_hadgem2_ao) General Circulation Models' climate data for 2050 under two scenarios RCP4.5 (moderately low emission scenario) and RCP8.5 (high emission scenario) were used.

To model crop suitability, FAO's EcoCrop Model was used. EcoCrop is an ecological niche model that uses crop's biophysical requirement to predict its suitability. Biophysical parameters used in the model are: Gmin (Minimum length of growing season in days); Gmax (maximum length of growing season; Tkill (temperature at which the plant dies); Tmin (minimum temperature at which the plant grows; Topmin (minimum optimum temperature for plant growth); Topmax (maximum optimum temperature for plant growth); Tmax (maximum temperature at which the plant grows); Rmin (minimum amount of rain water in mm required to grow); Ropmin (minimum amount of optimum rain water required to grow); Ropmax (maximum amount of optimum rain water required to grow); Rmax (maximum amount of rain water required to grow). Biophysical requirement of Apple and Mandarin Orange were adapted to Bhutanese condition to model crop suitability (Table 1).

Table 1. Biophysical parameters used in the model

Parameter	Apple	Mandarin	Unit
Gmin	180	120	Days
Gmax	320	300	Days
Tkmp	-12	-3	^{o}C
Tmin	4	10	^{o}C
Topmin	8	19	^{o}C
Topmax	17	28	^{o}C
Tmax	19	32	^{o}C
Rmin	500	800	mm
Ropmin	700	1200	mm
Ropmax	2500	1800	mm
Rmax	3200	3500	mm

Impact of climate change on crop suitability was assessed by first modeling the crop suitability under present and future climate scenarios and then comparing the two as given in Table 2. EcoCrop suitability model was run in R version 3.4.3like in other studies (CIAT, 2017; J. Ramirez-Villegas; L. Parker 2017). Outputs from R were imported into ArcGIS 10.5, reclassified using threshold level of 50% and above, overlaid with 2010 agriculture land use data and area estimated.

Table 2. Classification of potential impact of climate change on crop suitability area

Type	Description
No longer suitable	Areas suitable under present condition but not suitable under future scenario
Become less suitable	Areas suitable under present condition but become less suitable under future scenario
Remain same	Areas suitable under present condition and remain suitable under future scenario as well
New potential	Areas not suitable under present condition but become suitable under future scenario
Become more suitable	Areas suitable under present condition but become more suitable under future scenario

3. Results and Discussion

In general, crop physiology is greatly influenced by climate, especially temperature. Rise in temperature is projected to have both positive and negative effect. Usually with rise in temperature, areas in the upper reaches are expected to become suitable for crop cultivation. However, in Bhutan, even if the upper reaches become suitable in terms of climate, steep topographic features present serious challenge for crop husbandry. Hence, in general, climate change could lead to change in cropping systems itself.

3.1. Impact of climate change on Apple

Apple is one of the most important cash crops that have an established market for export. Further, it is a crop that thrives well under cool biophysical environment. In order to ascertain impact of climate change on apple suitability area, it was studied under two scenarios: Representative Concentration Pathways (RCP) 4.5 (moderately low level of net CO_2 emission) and 8.5 (high level of net CO_2emission) were studied. As expected apple suitability area loses more under RCP8.5 than RCP4.5.

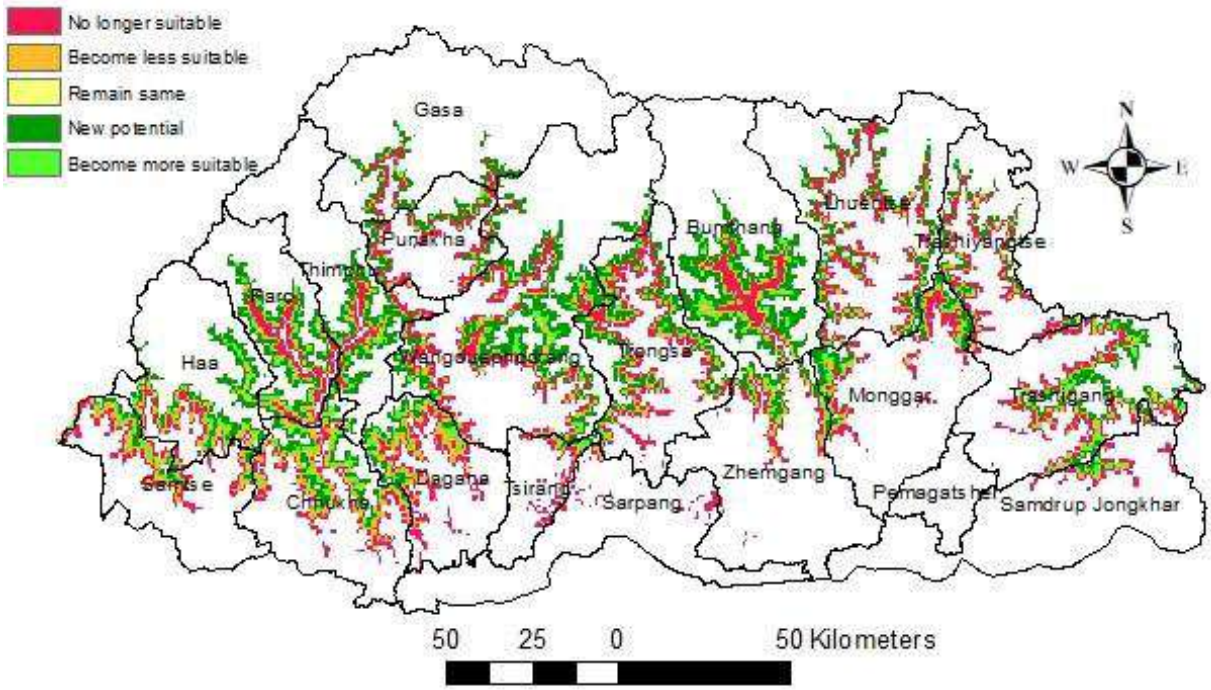

Figure 1. Impact of climate change on apple suitability under RCP4.5

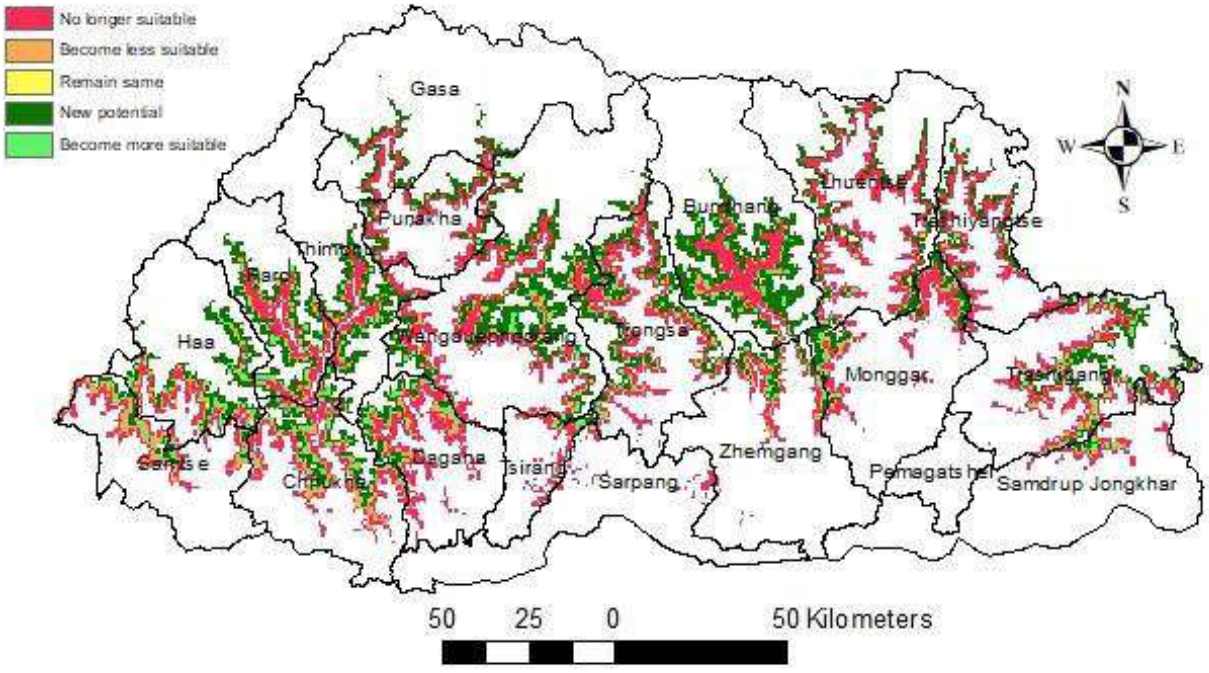

Figure 2. Impact of climate change on apple suitability under RCP8.5

3.2. Gainers and losers in Apple

On the whole, in 2050, Bhutan loses areas suitable for apple production under both the projected future climate scenario (Table 3). Under RCP4.5, Bhutan loses more than 15,000 acres of areas suitable for apple production and under RCP8.5, loses more than 16,000 acres. Under both the scenarios, all top apple producing Dzongkhags of Thimphu, Paro, Bumthang

and Chukha loses considerable chunk of areas suitable for apple production in 2050. Among the top five apple producing Dzongkhags, only Haa gains under both the scenarios.

Table 3. Net result of climate change on apple suitability area (acres) under two scenarios

Scenario	No longer suitable	Become less suitable	Remain same	New potential	Become more suitable	Net result
RCP4.5	28230	19010	802	12245	19963	-15032
RCP8.5	30641	14748	0	12282	16678	-16429

3.3. Impact of climate change on Mandarin Orange

Among the fruit crops, Mandarin orange is the top cash earners in the country. In 2016, more than 42,000 ton of mandarin orange were produced. Unlike apple, prospect for mandarin orange is much brighter under both projected scenarios. However, this study does not consider the likely increase in pests and disease pressure under increased temperature which could offset the gain made in terms of areas. Among the two scenarios, RCP4.5 provides better scope for mandarin production than RCP8.5.

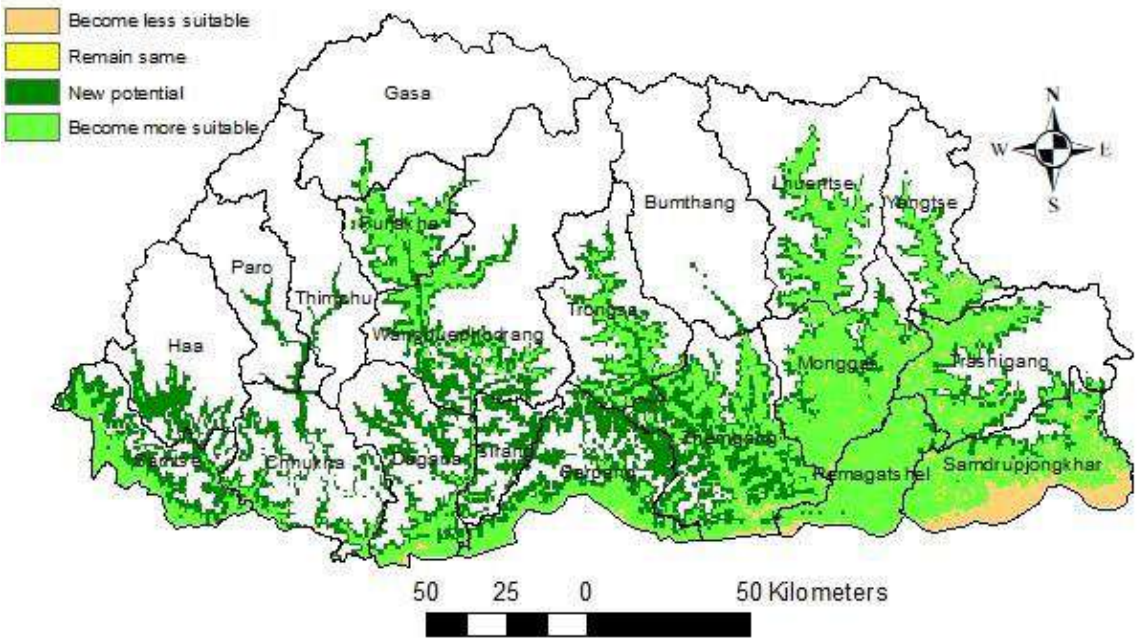

Figure 3. Impact of climate change on Mandarin orange suitability under RCP4.5

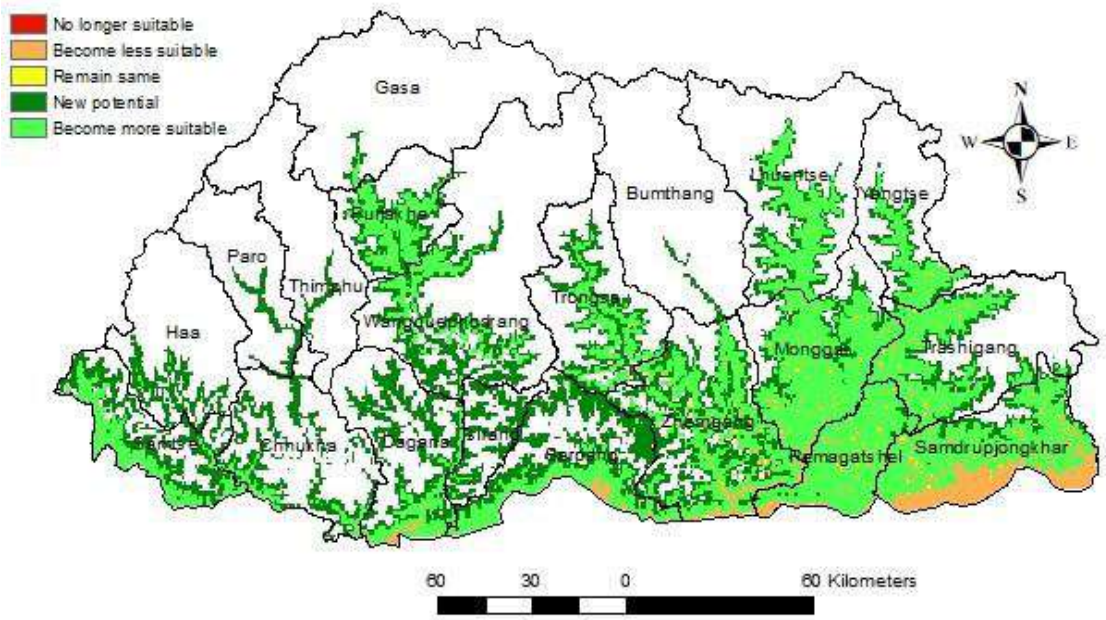

Figure 4. Impact of climate change on Mandarin orange suitability area under RCP8.5

3.4. Gainers under Mandarin orange

In general, notwithstanding other factors, climate change offers better prospect at least to the mandarin orange growers. In 2050, under the projected climate scenario RCP4.5, Bhutan gains more than 207,000 acres of land for mandarin orange production and more than 205,000 acres under RCP8.5. Under both the scenarios, Samtse, Punakha and Lhuentse Dzongkahgs are the biggest gainers.

Table 4. Net result of climate change on mandarin suitability area (acres) under two scenarios

Scenario	No longer suitable	Become less suitable	Remain same	New potential	Become more suitable	Net result
RCP4.5	0	23235	5004	76492	154125	207382
RCP8.5	6	25943	6687	79169	151951	205170

4. Conclusion

As for Apple, though some Dzongkhags gain and other lose, but on the whole, the model projects that Bhutan will lose quite a chunk of area for its cultivation both under the moderately low and high emission scenarios, especially for today's leading apple producing Dzongkhags. On the contrary, the model projects brighter prospects for mandarin orange growers under both the scenarios, provided rise in temperature does not exacerbate pests and disease incidences. Though any models should be read with caution, yet the analysis provides an interesting insight. It presents probable future scenarios – such as change in cropping systems andits impact on the income of the farming communities. It also tends to indicate that temperate crops are more likely to be impacted more than sub-tropical crops. Given these scenarios, diversification of crops, evaluation of biotic and abiotic stress tolerant crops,

awareness on climate change and its impact could provide some wherewithal to deal with potential impact of climate change on Agriculture. Though agriculture is climate dependent, availability of reliable national data is one of the biggest challenges. Hence, there is a need to set up automatic weather stations in different agro-ecological zones since climate changes even within short span of distance due to complex topographic features.

Acknowledgement

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Evaluation of Potting Mix on the Growth of Container-Grown Trifoliate Orange (*Poncirus trifoliata*)

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ABSTRACT

Effects of different potting mix on the growth and development of pre-germinated Trifoliate orange (Poncirus trifoliata) seedlings were studied in the greenhouse experiment at the Agriculture Research and Development Centre, Samtenling in two consecutive growing seasons. Cattle manure, coconut coir and composted saw dust were evaluated by mixing individually with coarse river sand at the ratio of 34% and 50% by volume and their performances were compared to the local standard potting mix (50% topsoil and 50% cattle manure volume/volume). The experiment was laid out in a randomized block design (RCBD) with five replications. Results obtained from the first year experiment showed that potting mix with 66% sand and 34% composted saw dust showed significant differences ($p < 0.05$) from other treatments in terms of incremental plant height (84.00 cm), but no significant differences were observed in incremental stem girth. Similar results were also observed in the second year experiment. The potting mix consisting of 66% sand + 34% composted saw dust, 50% sand + 50% cattle manure and 50% sand +50% composted sawdust showed high significant differences ($p < 0.01$) from other treatments in terms of incremental height where as potting mix of 50% sand + 50% composted saw dust produced the best seedling attributes in terms of stem girth (5.72 mm). The potting mix combination of 66% sand+ 34% composted saw dust was found to be best for the growth in terms of increase in height of trifoliate orange. For grafting purpose, potting mix combination of 50% sand + 50% composted saw dust could be used as it recorded the maximum increase in stem girth.

Keywords: *Citrus; Potting Mix; Growth; Stem Girth*

1. Introduction

Citrus is one of the largest and most important groups of fruits of tropical and subtropical regions (Khan et al 2006). In Bhutan, mandarin orange is grown in as many as seventeen Dzongkhags and it forms an integral part of livelihood and the main source of income for the majority of subsistence and small scale farmers. Citrus is commercially propagated through budding or grafting on seedling rootstocks. *Poncirus trifoliata* is most preferred rootstock for mandarin orange as it can withstand cold and wet conditions. It is also highly resistant to *Phytophthora* root and collar rots caused by the fungus *Phytophthora citrophthora* and to the citrus nematode (*Tylenchulus semipenetrans*). In addition, fruit quality is excellent as it has high total soluble solids and juice contents, and smooth thin peel (n.d. 2004).

In Bhutan topsoil is still used as one of the components of potting mix for citrus rootstock production. Although the topsoil being the uppermost layer of soil is a rich mixture of

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decaying organic matter and minerals, it may also contain the seeds of noxious weeds and harbor pests and soil-borne pathogens. Thus, if not sterilized, topsoil can be detrimental to seedling health. Besides, the topsoil is heavier for use in containers and usually clumps or packs when it is used as a sole potting mix. Packed soil prevents water from being distributed evenly and only certain portion of the mix gets soaked, affecting the health and growth of the seedlings (Kerry 2017). An optimal plant growth is essential for maximization of productivity. Healthy plants without deficiencies ensure optimal graft take and grow into more healthy and vigorous trees once they are planted in the field (Dekkers et al 2000). Good container-mix management is basic to the production of quality container-grown citrus nursery plants. The potting mix containing sand, manure, clay loam and sawdust were found effective for the healthy growth and development of troyer citrange grown in pots (Anvari et al 1992). Similarly potting mix containing different mixture of loam, sand and cattle manure (2:1:1) had a significant effect on growth of sour orange and troyer citrange container-grown seedlings (Nasir et al 1990).

Considering these issues with the use of topsoil, the Department of Agriculture (DoA) in collaboration with Australian Centre for International Agricultural Research (ACIAR) conducted an experiment to assess the effect of different potting mix suitable for container production practices for citrus. Currently little information is available on the effect of potting mix on the growth of citrus seedlings in Bhutan. Therefore, the aim of the research was to ascertain the effect of different potting mix on the growth of trifoliate orange (*Poncirus trifoliate*) seedlings for rootstock.

2. Materials and Method

The first year experiment was carried out from June 2014 to December 2014 at Agriculture Research Development Centre (ARDC) Samtenling. To confirm the finding of the first year result, the second experiment was conducted from June 2015 to November 2015. The greenhouse experiment was conducted in RCBD with seven treatments and five replications. In the first experiment, pre-germinated trifoliate orange (*Poncirus trifoliata*) seedlings of 3 month having average recorded height of 25.8 cm was used, and in the second experiment seedlings with average height of 25.1 cm was used. The compositions of seven different treatments are presented in Table 1.

Table 1. Different potting mix and its composition

Treatment	Composition	Ratio (%)
1	Topsoil + Cattle manure	50:50
2	Sand + Coir	66:34
3	Sand + Coir	50:50
4	Sand + Composted saw dust	66:34
5	Sand + Composted saw dust	50:50
6	Sand + Cattle manure	66:34
7	Sand + Cattle manure	50:50

The pH of all treatments was analyzed using pH kits and accordingly lime was added to raise the pH to 7.0 in all the mix. The physico-chemical property and major nutrient content of the mix were analyzed at Soil and Plant Analysis Laboratory (SPAL), Simtokha. Twenty gram of complex micronutrient (micromax) and slow release NPK fertilizer (Osmocote) were then added in each treatment. The seedlings, three months after germination, were transplanted to polybag (25 x 18 cm) filled with each mix tested. Each pot contained only one seedling and three replicate sets of pots were prepared for each treatment. Liquid fertilizer (Aquasol) at the rate of 4.5 gram in 9 liters of water was applied to the seedlings on weekly basis starting from two weeks of transplanting. Irrigation was provided with 200 mL of water on alternative day. The growth rate of seedling was measured in terms of plant height and stem diameter. The height of seedling was measured from potting mix surface up to the tip of the rootstock seedling. Stem diameter was measured each time at a point 5 cm above the crown. The observations on plant height were made on fortnightly interval whereas that on stem diameter was done at one month interval for a period of six months. One way analyses of variances (ANOVA) were performed with SAS (version 2002) and Duncan's Multiple Range Test (DMRT) was used in the mean comparison whenever they were statistically significant.

3. Results and Discussion

3.1. Results

The inherent physico-chemical properties of saw dust, topsoil and cattle manure are presented in Table 2. All the growth mix had pH within acidic (<7) range. The nitrogen percent (N %) of topsoil was within medium (0.2-0.5%) range, whereas N% content of cattle manure was within high (>0.5%) range. Composted saw dust had low (<0.2%) N% content. The potassium (K) content of saw dust and topsoil was within low (<100 mg/kg) range where K content in cattle manure was within high (>200) range. Similarly phosphorous (P) content of saw dust, topsoil and cattle manure were within high (>30) range (NSSC 2017)

Table 2. Physico-chemical properties of growth media

Growth media	pH	C:N Ratio	N (%)	K (mg/kg)	P (mg/kg)
Composted saw dust	4.86	113.7	0.04	81.5	108.3
Topsoil	4.62	15.5	0.28	92.2	115.1
Cattle manure	4.93	---	0.67	969.1	795.7

Citrus seedling grown in potting mix comprising of 66% sand + 34% composted saw dust had the highest value (84 cm) for plant height as shown in Table 3. This was significantly higher (P<0.05) than other treatments except seedlings grown in potting mix containing 50% topsoil +50% cattle manure (76.80 cm), 66% sand+34 % coir (79.40 cm), 50% sand + 50% composted saw dust (79.80 cm), 66% sand+34% cattle manure (73.80 cm) and 50% sand +50% cattle manure (81.60 cm). The lowest value for plant height was obtained in 50% sand + 50% coir (70.90 cm) (Table 4). No significant difference was observed amongst the treatments in terms of incremental diameter (Table 4). Similar results were observed in the

second experiment (Table 5). The potting mix combination of 66% sand +34% composted saw dust was highly significant (P<0.01) than other treatments except 50% sand +50% composted saw dust and 50% sand +50% cattle manure. The highest incremental in height (88 cm) was observed in potting mix 66% sand +34% composted saw dust whereas the lowest incremental in height (70 cm) was observed in potting mix 66% sand +34% cattle manure. In the second year experiment significant differences (P<0.05) was observed in the incremental stem girth (Table 5). Potting mix of 50% sand + 50% composted saw dust was significantly higher than other treatments except 50% sand + 50% cattle manure, 66% sand+34% coir, 50% topsoil + 50% cattle manure, 50% sand + 50% coir and 55% sand + 50% composted saw dust. The highest incremental growth on stem girth (5.72 mm) was observed in potting mix containing 50% sand + 50% composted saw dust whereas the lowest incremental growth (3.95 mm) was observed in potting mix 66% Sand +34% cattle manure.

Table 3. Effects of different potting mixes on the height and stem girth of trifoliate orange seedlings

Potting mix	Plant height (cm/plant)			Stem girth (mm/plant)		
	Initial	Final	Incremental	Initial	Final	Incremental
66% sand+34% composted saw dust	26.0	110.0	84.0	2.2	7.46	5.26
50% sand+50% cattle manure	24.0	105.6	81.6	2.0	7.55	5.55
66% sand+34% coir	24.6	104.0	79.4	1.7	7.43	5.73
66% sand+34% cattle manure	27.0	100.8	73.8	2.2	7.19	4.99
50% topsoil+50% cattle manure	25.0	101.8	76.8	1.9	7.00	5.10
50% sand+50% coir	26.8	97.70	70.9	2.4	8.39	5.99
50% sand+50% composted saw dust	27.2	107.0	79.8	2.2	7.59	5.39

Table 4. Effects of different potting mixes on the incremental plant height and stem girth of trifoliate orange seedlings over six month in the first year experiment.

Potting mix	Incremental plant height (cm/plant)	Incremental stem girth (mm/plant)
66% sand+34% composted saw dust	84.00 a	5.26
50% sand+50% cattle manure	81.60 ab	5.55
66% sand+34% coir	79.40 ab	5.73
66% sand+34% cattle manure	73.80 ab	4.99
50% Topsoil+50% cattle manure	76.80 ab	5.10
50% sand+50% coir	70.90	5.99
50% sand+50% composted saw dust	79.80 ab	5.39
CV (%)	11.02	15.64
Pr > F	0.258	0.533
F Test	*	ns

Table 5. Effects of potting mix on the incremental plant height and stem girth observed over a period of six months in the second year experiment.

Potting mix	Incremental plant height (cm/plant)	Incremental stem girth (mm/plant)
66% sand+34% composted saw dust	88.00 a	5.58 a
50% sand+50% cattle manure	82.30 ab	4.18 ab
66% sand+34% coir	75.50 c	4.98 a
66% sand+34% cattle manure	70.00 d	3.95 b
50% Topsoil+50% cattle manure	78.20 b	4.50 ab
50% sand+50% coir	70.10 d	4.94 a
50% sand+50% composted saw dust	80.00 ab	5.72 a
CV (%)	12.7	10.9
F Test	* *	*

3.2. Discussion

A good potting soil or mix should be porous enough for root aeration and drainage, and capable of retaining water and nutrients. A potting mix that contains an adequate supply of nutrients is essential for plants to attain maximum growth and development. The balanced potting mix greatly affects the plant height and availability of growing substrate with the supplement of essential nutrients is essential for attaining maximum plant height (Ikram et al 2012). The result from our study showed that different potting mix influenced both plant height and stem girth differently. In both the experiments, maximum increase in plant height was observed in 66% sand+ 34% composted saw dust. Significant difference was observed in incremental stem girth in the second year experiment. The potting mix of 50% sand +50% composted saw dust and 66% sand+34% composted saw dust showed the maximum increase in the stem girth.

Although the physico-chemical analysis showed higher content of major nutrients in cattle manure compared to the composted saw dust, the potting mix containing topsoil and cattle manure could not yield maximum increase in height nor in stem girth. This could be due to soil clumping or packing of potting mixes as packed soil prevents water from being distributed evenly. Accordingly to Kerry (2017), part of the mix becomes soaked, while the other part remains dry which hampers the healthy growth of the seedlings. The result also reveals that both the physical and chemical properties of potting mix are as important as their nutrient content in promoting the plant growth. On the other hand, the probable reason for better growth of trifoliate seedlings in composted saw dust could be beneficial effect of compost. Compost plays a crucial role in improving physical, chemical and biological properties of the soil and potting mix. As an organic matter, compost also improves the plant growth indirectly through increasing the microbial activity. Compost contains numerous beneficial microorganisms (bacteria and fungi) and these microbes form symbiotic, or mutually rewarding, partnerships with plant roots, making them possible for plants to feed themselves more efficiently. Further, most nutrients in compost are in organic form which are released slowly and are less likely to losses through leaching. There are also reports that compost and organic fertilizers can work together. The organic matter in compost sponges up the fertilizer nutrients until they are needed by plants. Compost also provides many nutrients

that plants need in small amounts (micronutrient), such as boron. The other reason could be due to the suppressive property of compost on soil-borne plant diseases through beneficial microbes, which in turn helps in vigorous growth of the plant grown in composted saw dust. Our findings are in line with that of Dorji et al (2015) who reported the maximum increase in the stem girth and maximum the height of citrus seedlings in potting mix containing 50% sand and 50% composted saw dust, and 66% sand + 34% composted saw dust respectively.

4. Conclusion

The potting mix combination of 66% sand+ 34% composted saw dust was found to be best for growth in terms of increase in height of trifoliate orange. For grafting purpose, potting mix combination of 50% sand + 50% composted saw dust could be used as it recorded the maximum increase in stem girth. The physic-chemical properties of local cattle manure showed high content of major nutrients as compared to other (sand, sawdust, coconut coir) used in the experiment. Therefore, with proper soil amendments potting mix combination of topsoil (sterilized) and cattle manure could also be used for growth of citrus rootstock and seedling in future.

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Crop suitability modeling for rice under future climate scenario in Bhutan

Ngawang Chhogyel[n], Mahesh Ghimiray[n] and Kiran Subedi[o]

ABSTRACT

A crop suitability modeling for rice under the current and projected future climate (2050) under two global emission scenarios (RCP4.5 and RCP 8.5) was done using EcoCrop model. The objectives of the study are (1) to assess suitability of rice under the current climatic condition (2) develop crop suitability model for rice under future projected climate, and (3) analyze loss and gain in areas under changing climatic condition to help plan for rice research and development. The model shows that the crop suitability is changing under projected future scenario and the changes in suitability is going to have major effect on rice production in the country. One of the major findings of the study was that, Bhutan could gain in suitability and thus, has opportunity for more initiatives for rice commodity. The gain in area under projected future climate would contribute to rice self sufficiency, thus, calling for enhanced investment in the 12th five year plan and beyond.

Keywords: *Climate; Crop modeling; Crop suitability; Rice*

1. Introduction

Rice is the most important staple food of the world that feeds more population than any other crops. The International Rice Research Institute (IRRI) in the Philippines has reported that rice feeds 4 billion, or 56% of the world population (IRRI 2016), thus becoming the most important crop on earth. Though in Bhutan area under rice and production is meagre among the Asian countries, rice in Bhutan is more than just food for the country. It is often equated with food security and regarded as the living culture, way of life, national pride, heritage, religion and a symbol for environmental and landscape beauty. It is consumed three times a day (Chhogyel et al 2015) and constitutes 53% of daily dietary calorific value of Bhutanese (Chettri et al 2015). Worldwide, including Bhutan, there is an increasing trend both in terms of production and productivity. However, the production and productivity gains are not able to keep pace with the rapidly rising demand for rice due to population growth. Further, climate change seriously threatens rice production that is required to feed the rising future population (IRRI, 2016). Therefore, rice that requires the maximum water than any agricultural crop is going to be affected the most by the impacts of climate change (GRiSP 2013). Under changing climate, the challenge is to produce more grains from less land, less water at a higher cost of production (Gujja & Thiyagarajan 2010).

Rice in Bhutan is particularly vulnerable to climate change due to shorter growing period, mountainous terrain and various bio- physical factors. Climate change induced changes such as changes in temperature regimes; rainfall pattern and increasing variability in extreme events are going to adversely affect crop production. The Intergovernmental Panel on

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Climate Change (IPCC) reports that the average global surface temperature has increased by 0.85°C over the period 1880 to 2012 (IPCC 2013). Higher levels of CO_2 and temperature might devastate crop production due to their effect on physiological performance especially in the mountain ecosystems. While there are opportunities to slightly increase photosynthesis from elevated CO_2 level in the atmosphere, there is going to be an overall reduction in productivity due to high temperature (IPCC 2007a). With Bhutan's location in the temperate region of the world, literally there is no problem of high temperature stress, but shifting precipitation and impending drought is the main concern for rice production. Majority of the rice fields are dependent on monsoon rain, or monsoon charged streams for irrigation. Slight change in timing, duration and intensity of rain could have disastrous effects on crop production. Worldwide, 27 million hectares of rain-fed rice is affected by drought (GRiSP 2013; IPCC 2007a) and in Bhutan's case, there is a dearth of studies but it is estimated that drought conditions affect up to 20% of rice area annually. Thus, rice is under threat from the vagaries of weather and impacts of climate change since window period for cropping is very short. Moreover, the changes in diurnal fluctuations in temperatures in the mountainous slopes of Himalayas are considered unfavourable for rice, adversely affecting production.

It is estimated that global mean temperature would rise by 1^oC above the current temperature by 2025 and 3^oC by the turn of the century (IPCC 2002). This is going to severely affect crop production and calls for changes in management options. Under climate change scenario, Bhutan might gain additional area since rice cultivation would move to higher temperate areas. However, this slight area gain would not be commensurate to large area loss in other parts due to drought, increased frequency of extreme weather events and other factors. Overall, the climate change might change rice agro-ecological pattern and it is worth projecting areas based on global climate models for the development of climate resilient adaption and mitigation strategies. Thus, this paper is an attempt to assess crop suitability in the projected future climate scenarios and analyze loss and gain in areas between current and 2050 period.

2. Materials and Methods

The crop suitability analysis for rice for Bhutan was based on the 40% threshold suitability (μ) which was derived using the following simple formula:

$$\mu = \frac{(A + a) + (B + b) + (C + c)}{N}$$

Where A, B, C, were the percent high altitude, mid-altitude and low altitude rice areas with a, b and c as the estimated rice high, mid and low altitude rice areas across the agro-ecological zones as presented in the table 1 below.

Table 1. Estimation of rice areas across the rice ecologies and derivation of 40% crop suitability threshold used in the modeling

Sl. No	Particulars	Area (%)	Total area (%)
1	A=High Altitude rice	20	25
	a=High Altitude rice in mid-elev	5	
2	B=Mid-altitude rice	40	47
	High & low alt. rice	7	
3	C=Low Altitude rice	40	48
	c=Low Altitude rice in mid-altitude	8	
N	Average		40

The world climate data for both current and future (2050) was used for the generation of crop suitability maps. For national boundary, land use and elevation maps, data were sourced from the national geo portal, www.geo.gov.bt

Crop parameters for rice were developed based on the eco-crop model of DIVAGIS Eco-crop tool and crop requirements in the context of Bhutan. The crop parameter which is an average of *indica* and *japonica* rice is as presented in the table 2.

Table 2. Eco-crop parameters used for the analysis of crop suitability for rice

Parameters	Rice	Remarks
Gmin	110	Growing days
Gmax	180	
Tkmp	40	in x^0 C (x 10)
Tmin	110	
Topmin	210	
Topmax	280	
Tmax	340	
Rmin	950	in mm
Ropmin	1500	
Ropmax	2000	
Rmax	3900	

X: temperature in degree centigrade

The rice agro-ecosystem map of Bhutan was developed using the ArcGIS showing the three broad zones: high altitude, mid-altitude and low altitude rice (Figure 1).

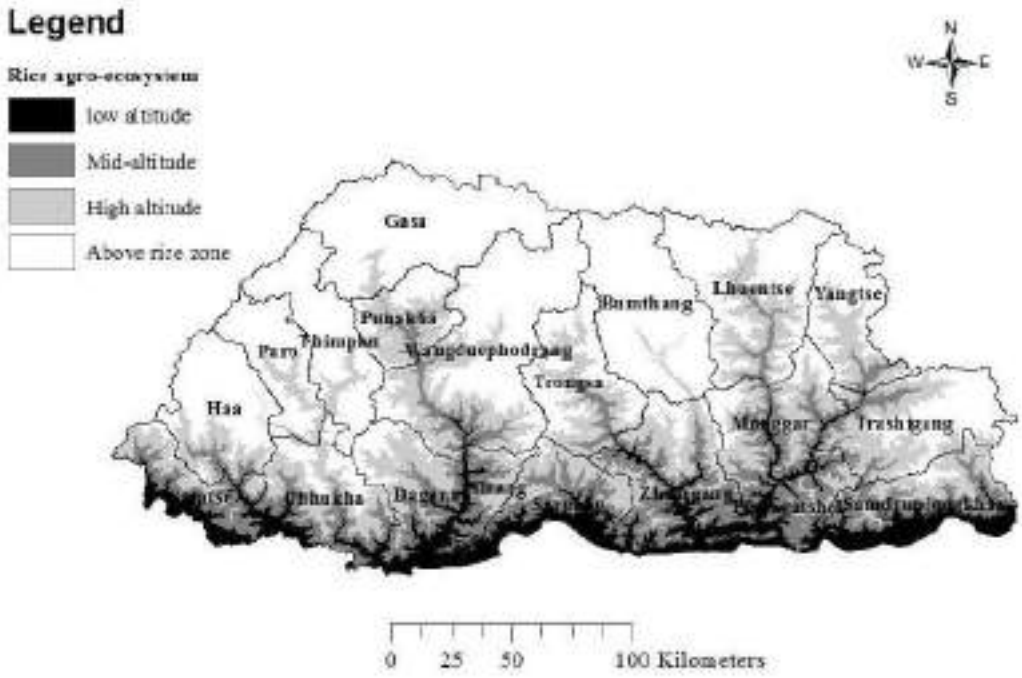

Figure 1. Map of Bhutan showing three broad rice agro-ecologies

The suitability maps were generated using the combination of Arc GIS version 9.3 tools and statistical software "R". Climate projections for 2050, an average of two different global emission scenarios, RCP 8.5 and RCP 4.5, which were predicted using 31 global circulation models (GCM) was used.

3. Result and Discussion

3.1. Results

The crop suitability map for the current climatic condition showed that rice cultivation is more suitable in the south and mid-altitude valleys (Figure 2). Under the present temperature and precipitation pattern, suitable areas for rice in the mid-altitude zone extends northwards along the valleys of Kurichu, Dangmechhu, Mangdechu, Puna Tsangchhu and Amochu. Areas away from the valleys and into the upper slopes are not suitable for rice.

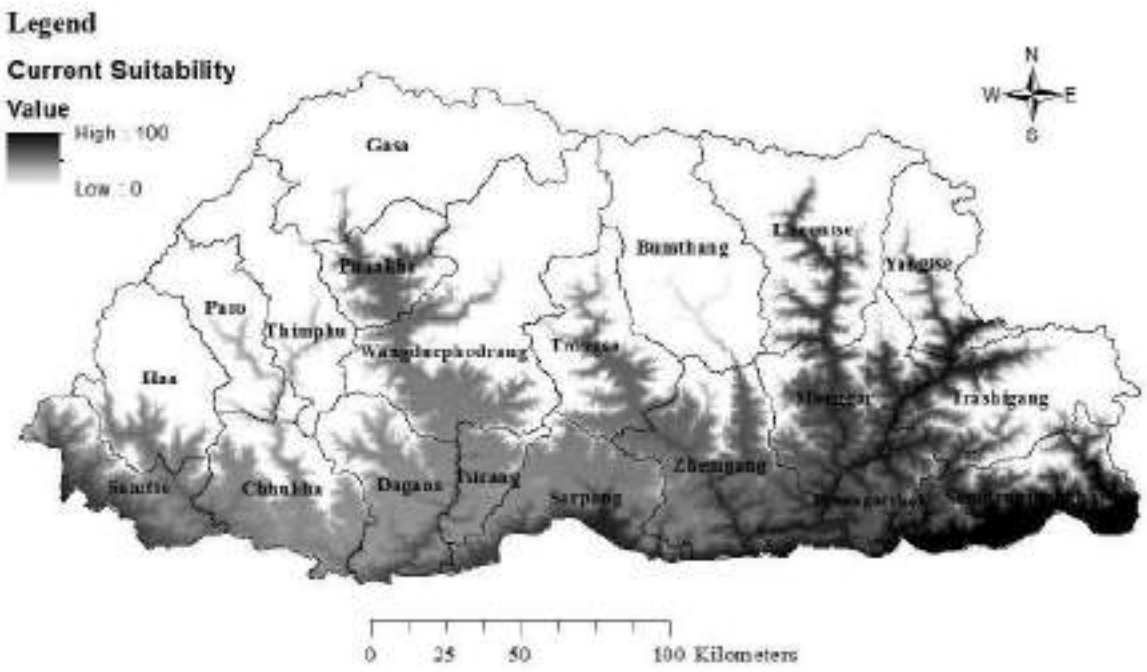

Figure 2. Crop suitability of rice under the current climatic conditions of temperature and precipitation

Rice suitability under the projected future climate (2050) showed that rice suitability actually increases across the country (Figure 3). The suitable areas are broader in the future suitability map. Suitability changes happen in all the three agro-ecosystems (Figure 4).

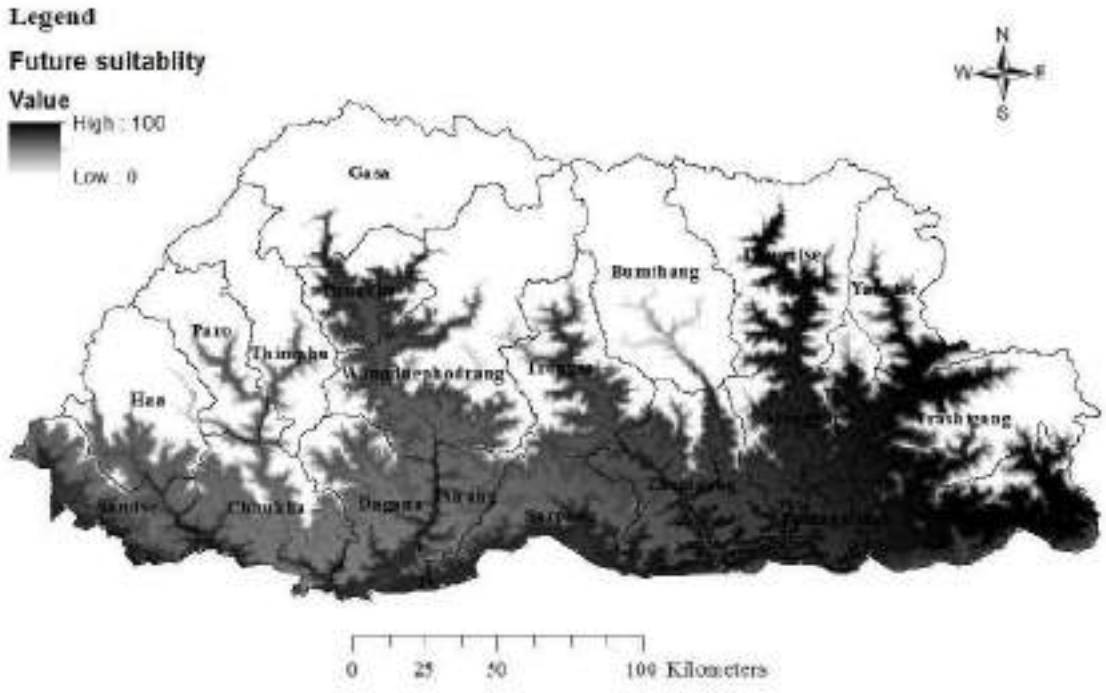

Figure 3. Crop suitability of rice under the future (2050) projected climatic conditions of temperature and precipitation

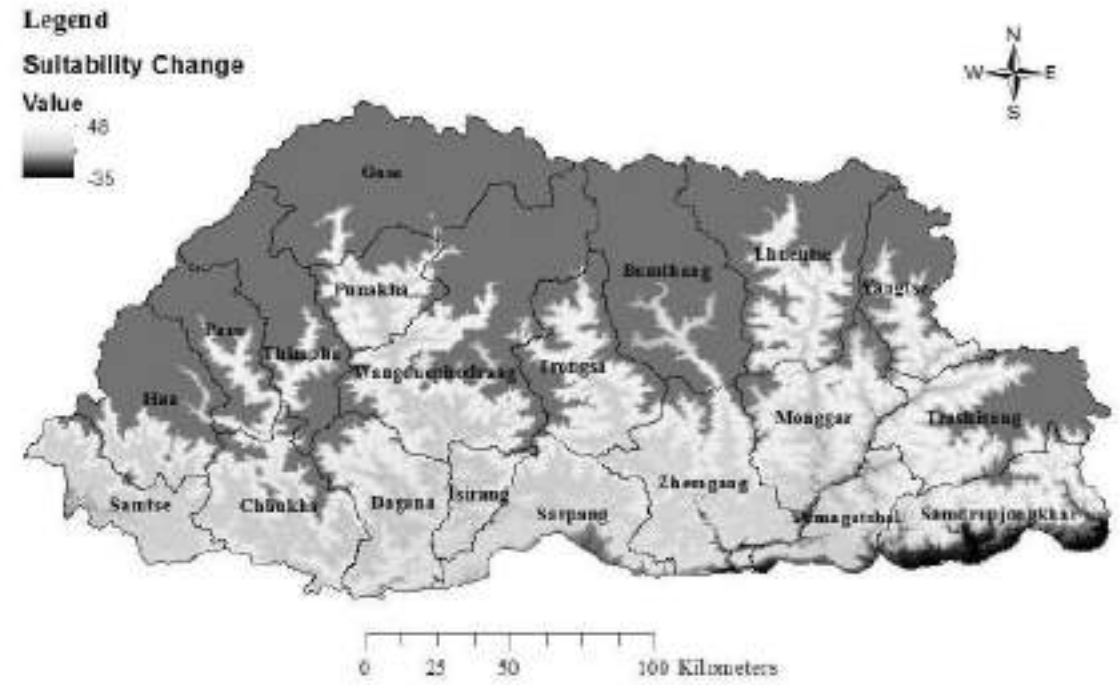

Figure 4. Crop suitability change from the current to future (2050) projected climatic conditions of temperature and precipitation

4. Discussions

The crop suitability maps of rice under present and future projected climatic conditions revealed stark variations across the three agro-ecological zones. Crop suitability for rice under the current condition is limited to just the southern belt and narrow tracts of land in the mid-altitude zones. This also indicates that the land is flatter and more suitable for rice cultivation in the valleys and southern regions. The technical report on Bhutan land assessment 2010 showed that that rice areas are more concentrated in the river valleys and southern belts (NSSC and PPD 2011). This indicates that availability of irrigation water and topography affects suitability.

Under the projected 2050 climate, there is an overall expansion in suitability areas; thus, the suitable zones were broader compared to the present condition. This shows that Bhutan actually has an opportunity to go for horizontal expansion of rice area. However, there are topographic and bio-physical limitations to increase area for production. Thus, scope for increasing rice area in the foreseeable future may be limited by topographic features though more area becomes suitable in terms of climate. Overall, there is a net gain of 5432.78 ac (Table 3) in 2050 which should be accounted for the rise in temperature in the upper cooler part of the country. This is just about 10% increase in suitability and is an indication that rice cultivation would continue to be suitable for Bhutan. Yoshida (1981) mentioned that rice requires an optimum temperature range of 20-30 ^{o}C from seed germination to ripening. Thus, the projection shows that increasing temperature for the rice areas in higher elevations in Bhutan would reduce cold stress and make rice more favourable.

Table 3. Area gain and loss under current and future climates in Bhutan

Sl. No	Categories	Area (ac)
1	Current Suitable	53719.98
2	Future suitable	59152.76
	Net suitability gain	5432.78

The suitable rice area obtained from the current study is more or less equal to the actual cultivated area of 53,055 acres (DoA 2016). Since the analysis is based on just 40% threshold, the country might still be having more suitable areas for rice. However, combination of temperature rise and other stresses have tendency to reduce crop yield. The national average rice yield is only 1,604 kg per acre (DoA 2016) with greater potential for increase. Therefore, with only 10 % increase in area in 2050, research could focus more on yield increase (vertical expansion) through various climate resilient interventions like appropriate varieties, integrated soil fertility management, assured irrigation, integrated pest and disease management and addressing post harvest losses. Investments in response of climate change not only need more dedicated expenditures but also qualitative shift in overall composition of expenditures over time that will maximize potential synergies (CDDE and UNDP, 2013).

5. Conclusion

The crop suitability modeling exercise for rice showed that there are variations between current and future suitability. The current suitability map indicates that rice is mainly grown in lower elevations and crop modeling for the projected future climate in 2050showed increase in overall suitability. Based on the model, it is possible for Bhutan to expand rice area in places with abundant water resources and flatter areas. However, the suitability changes are quite pronounced across the entire rice agro-ecological zones. Thus, climate resilient technologies might have to be developed and promoted for sustainable rice production in the country. For the larger suitability changes, stress tolerant varieties including improved management practices will have to be the priority areas for research and development in rice.

Acknowledgement

The authors would like to extend gratitude to the Department of Agriculture, MoAF for capacity building initiative on crop suitability modeling exercise and UNEP for funding the programme. Special gratitude is also extended to Mr. Louis Parker and Nora for being great resource persons.

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Economic analysis of spring rice production at Rinchengang, Wangduephodrang

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ABSTRACT

An economic analysis of spring rice cultivation at Rinchengang, Wangdue District was carried out to determine the cost effectiveness of spring rice cultivation. A total of 45 households engaged in spring rice cultivation with input support in the form of free seeds, polythene sheets and fertilisers from the ARDC Bajo were interviewed. An analysis of cost and returns of the practice indicated that spring rice cultivation is indeed not economical owing to low yield and high production costs. Rice is a labour intensive crop and the spring rice production costs do not vary much with that of the main season crop, however the yield is quite low leading to comparatively lower economic returns for spring paddy. Attack from birds was found to be the main reason behind the lower yield in spring rice causing up to 60-80% of yield damage. This was also identified to be one of the main reasons behind farmers decreasing interest in spring paddy. Other factors such as labour shortage, high labour costs and low levels of farm mechanization were found to be restraining spring rice in the region. In order to enhance spring rice cultivation and to encourage more farmers, the study identified the need for a sustainable bird control mechanism, without which spring rice promotion initiatives may not succeed.

Keywords: *Double cropping; costs, labour; material; yield*

1. Introduction

Rice is the most important crop in Bhutan in terms of production and is often equated with food security of the country (Chhogyel et al 2015). The Department of Agriculture (DoA) with the mandate of enhancing agricultural production to meet the domestic food demand has put in concerted efforts towards the realization of self-sufficiency objectives. The various developmental interventions over the years have resulted in enhanced production and productivity. However, Bhutan continues to import more than 50% of its rice requirement from India. The domestic rice productions hardly meets 50% of the total rice requirement (Shrestha 2004). According to the latest statistics, rice is cultivated on 49,325 ac of land with a total production of 80,261 tonnes (DoA 2015).

Limited land holding is identified as the major constraint to the country's rice production enhancement (Chhogyel et al 2015, Shrestha, 2004). Of the total geographical area of 38,394 sq. km, the arable land comprises 7.8% (LUPP 1995) and the actual cultivated land comprises only 2.93% (NSSC and PPD 2010). The presence of mountains and rugged terrains renders most of the land unsuitable for cultivation (Hussein 2009; Neuhoff et al 2014). Crop intensification interventions such as double cropping, cultivation of fallow lands, mechanized

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farming and crop diversification are needed to enhance rice self-sufficiency. The global rice demand and trade outlook highlights the need to intensify rice production in Asia to meet the rising demand as there are limited possibilities of expanding the cultivation area (FAO 2014).

The double cropping practice can play an important role in achieving food self-sufficiency by doubling production through offering an opportunity to utilize scarce wetlands twice a year (Andrews and Kassam 1976). In china, rice double cropping contributes to 34.6% of country's rice production (He et al 2017). The spring rice concept was first introduced in the country in the early 1980s under the IFAD project to enhance paddy production for household self-sufficiency. The initiative continued for over a decade until it ceased in 2002 with the termination of the project (Chhogyel et al 2014a). In 2012-2013 the Research and Development Centre (RDC) Bajo took the initiative to revive the spring rice cultivation at Rinchengang, Wangdue, which has been one of the prime cultivators of spring rice ever since the inception of the practice in the country (Chhogyel et al 2015). Currently the farmers of Rinchengang cultivate spring rice on about 30 ac land belonging to forty-four households (HHs). Despite various government interventions to promote spring rice, the practice has not picked up. According to records maintained at ARDC Bajo, the area under spring rice continues to lag below 100 acres although the initial projection was to bring entire rice fields of Rinchengang under double cropping system (RNR RDC-Bajo 2013-2014).

With many practical issues raised by the growers, it is difficult to substantiate if the spring rice cultivation is economical for the farmers. This study is an attempt to understand the costs and returns involved in growing spring rice to help determine cost-effectiveness of the practice. The other objectives of the study are to quantify inputs, labour and materials required for spring rice cultivation and to determine the drivers and constraints of spring rice production. Such an understanding on cost and returns of the crop production would also help to assess the economic impacts of any new technologies.

2. Materials and Methods

2.1. Sampling

Rinchengang chiwog (sub-block) under Thedtsho Geowg (block) of Wangdue Dzongkhag was identified as the study site (Figure 1). The chiwog has 44 HHs involved in spring rice cultivation with 28.49 acres under cultivation. Employing a purposive sampling method, 100% sampling of all the 44 HHs was done. The respondents constituted 16 men and 28 women.

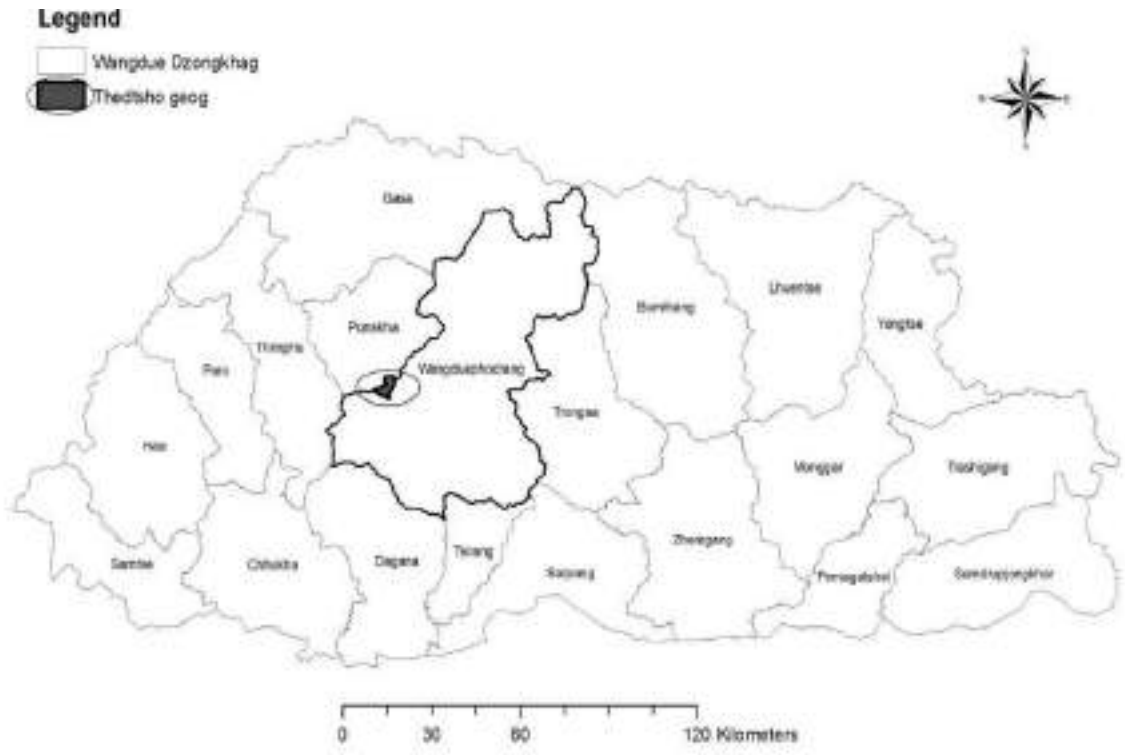

Figure 1. Map of Bhutan showing Rinchengang village (study site) under Thedtsho geog

2.2. Data collection

An open-ended survey questionnaire was designed to collect data. Farmers were asked about their labour and material inputs and outputs from their fields. Individual interviews with each of the 44 HHs were conducted. Subjective questions on farmer's attitude towards the technology and major issues with regards to the technology were asked. Data on farm machine hiring rates, hours of power tiller, thresher and rotovators required for a given plot of land were traced from the Agriculture Machinery Centre (AMC).

2.3. Data analysis

Data was entered in a data entry form in MS EXCEL, which consisted of several worksheets linked together. Data analysis was done in MS excel.

3. Results and Discussion

3.1.Labour distribution

The study showed that there were variations in labour requirement for different farm activities from nursery to harvesting of the crop. Spring rice cultivation requires a total of 45 men-days per acre of land (Table 1). Maximum labour was required for weeding and transplanting operations which constituted 19.5% and 15.9% men-days respectively. Harvesting activity with 6 men-days closely followed transplanting. The least labour requiring activities were terrace wall clearings, bund maintenance and grain cleaning with just one labour per acre.

Table 1. Labour days required for different farm activities

Farm activities	No. of Days	Percentage (%)	Std. deviation
Nursery	4	8.6	1.5
FYM	5	10.8	2.1
Terrace wall Maintenance	1	2.3	1.1
Ploughing	4	8.8	5.7
Irrigation	2	4.4	1.0
Bund Maintenance	1	3.2	0.6
Transplanting	7	15.9	2.3
Weeding	9	19.5	3.9
Harvesting	6	14.0	2.3
Threshing	4	7.9	1.5
Winnowing	1	2.0	0.5
Spraying of fertilizers/pesticides	1	2.4	0.2
Total	45	100	23

In rice farming, weeding and transplanting are considered the toughest activities and often portrayed as a backbreaking experience. Weeds form a major biotic constraint in Bhutan's farming system and increased labour input for rice transplanting is a major disadvantage (Ghimiray et al 2008). As in most Asian countries, the study found that labour requirements are largely met through household and exchange labour (Wang et al 2012). Only few farmers cultivating more than one acre of land practice labour hiring to meet the need for the additional farm activities. The labour requirement will be higher if post-harvest activities such as grain cleaning, grading, packing and transporting the produce to their houses which are often located away from the fields are included. The high labour requirement is directly attributed to low farm mechanization (Tobgay 2005). Most of the rice fields in the country are narrow and are not machine friendly. The smaller land holdings of Rinchengang farmers also offer limited option for farm mechanization. However, the use of power tillers is getting popular in land preparation activity (Chhogyel et al 2014b).

3.2. Labour costs

Amongst the farm activities, weeding takes the highest share of labour cost (20%) followed by transplanting (16%) and harvesting (14%) (Figure 2). The precent shares of farm labour cost for farmyard manure application; land preparation and nursery operations were 11%, 10% and 9% respectively. Activities such as terrace wall clearing (2%), bund maintenance (3%), threshing (8%) and winnowing (2%) had the lowest cost. The 45 labour days required for an acre of spring rice production is equated in terms of monetary value to a total cost of Nu.19, 967/acre. Similarly, weeding and transplanting activities are valued at a cost of Nu 3,983.90/acre and Nu 3204/acre respectively. Harvesting activity costed Nu 2842.5/acre, closely followed by manure application at Nu 2500/acre (Figure 3).

The farm labour is getting scarce and the daily wage rate has been increasing in the recent years. Currently, the labour wage rate at Rinchengang is Nu 350/day plus Nu 150 accounted for food and refreshment. Although there are not many studies on labour cost trends in

Bhutan, experiences showed that the daily labour wage would be anywhere between Nu 300 to 600/day depending on types of activities and cropping season. This daily wage rate depicted in the current study is fairly similar to the wage rate in Sri Lanka at USD $ 5/day/person which is amongst the highest in South Asia (Wang et al 2012). This shows that the labour wage in Bhutan is high and more initiative and interventions would be required to mechanize rice farming. The DoA has set targets to bring increased area under mechanization in the 11th Five Year Plan (PPD, 2013).

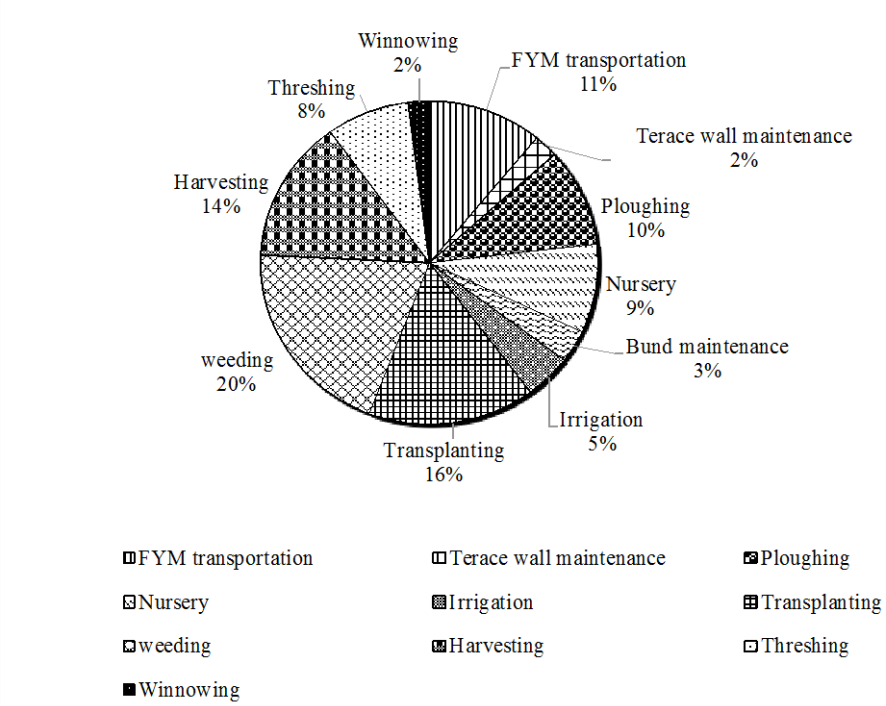

Figure 2. Percent share of costs for different farm activities

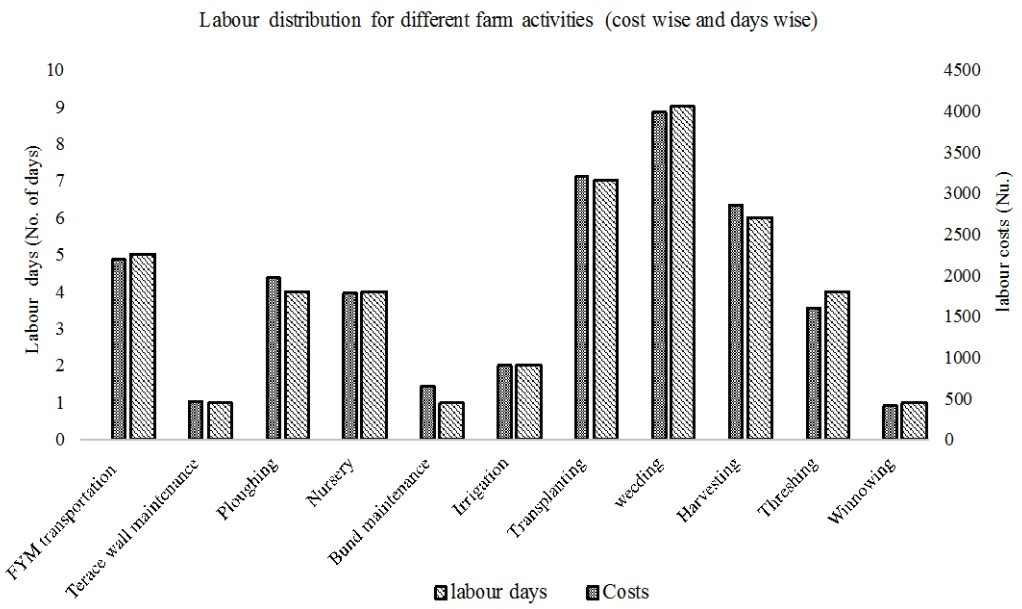

Figure 3. Labour requirement for different activities and its corresponding costs

3.3. Material inputs

In the main field, 53% of the total cost is constituted by power tiller hiring, followed by fertilizers costs at 19% (Figure 4). Cost of hiring thresher constitutes 14% and weedicide 7% of the total inputs costs. It was observed that all farmers produce and use their own FYM. For cost computation, Nu 0.5 per kg of FYM was taken which constituted 7% of the total material costs. In the nursery, seed and polythene sheet constituted more than 90% of the total material costs. According to Chhogyel et al (2014b), for spring rice production, nursery must be developed under protected condition (poly tunnel) due to low temperatures during seedling production. Thus, to encourage rice double cropping, subsidy in the form of poly tunnels and seeds are being provided by the government.

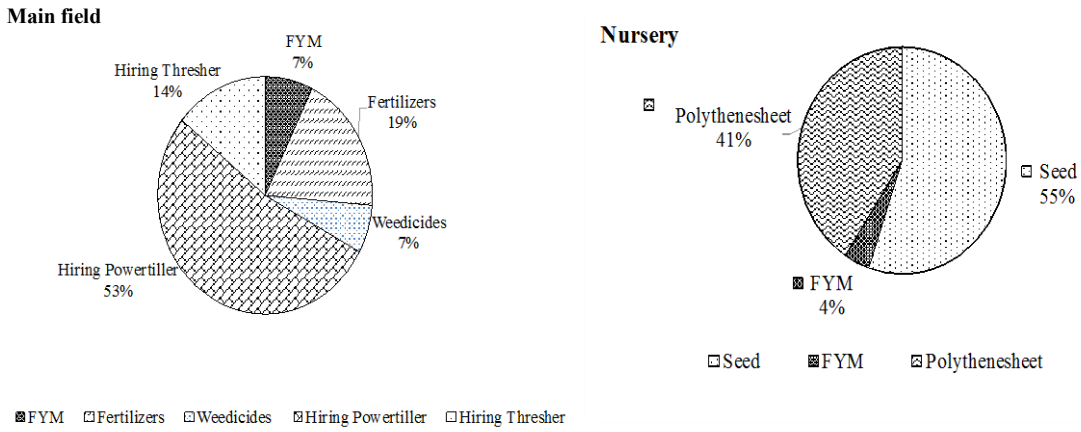

Figure 4. Material costs in the main field and nursery

3.4. Total costs

The two components determining the costs are material and labour costs. The main inputs in spring rice include seeds, polythene sheets, herbicides and farmyard manure. Other inputs such as irrigation water and rental cost of land are overlooked since these have no direct implications in the production cost. The cost of labour constituted 64% of the total cost in the main field while it contributed 6% of the total costs in the nursery (Table 2). Cost of input materials in the nursery was 6% as against 24% in the main field. As shown in Table 2, labour cost constituted major share (64%) of the total costs which translated to a total cost of Nu19967.5/acre. Material costs comprise the remaining 30% of the total costs valued at a sum of Nu 8526.4/acre. The wide variation between labour and input cost shows that there is need for major intervention to reduce the drudgery of rice farming through farm mechanization.

Table 2. Proportion of total labour and material cost

Activities	Costs (Nu)	Percent share (%)
Nursery inputs	1658.1	6
Inputs in the main field	6868.3	24
Labour costs (Nursery)	1774.4	6
Labour costs (Main field)	18193.1	64
TOTAL COSTS	28493.9	100.0

3.5. Crop guarding

Bird attack is a major issue in spring rice that results in significant yield losses. Spring rice is an off-season crop and being cultivated on a smaller tract of land, makes it highly vulnerable to bird attack. An ideal guarding requires farmers to spend about 10-11(from dawn to dusk) hours in the field for nearly1.5 months protecting their crop from bird attack. Birds are seen attacking the crop from early morning till dark and from grain filling stage till harvesting. This works out to a total of 30-40 men-days per acre which is very high. In most cases, elderly persons or younger children are engaged in crop guarding. In the absence of such people at home, farmers leave their fields unguarded. The absence of crop guarding is one of the main reasons for low yield of spring rice. The cost of production computed in this study does not include the crop guarding cost.

3.6. Yield, costs of production and net returns

The study showed that the average paddy yield without crop guarding was 0.65 ton/ac. Based on this, the average cost of production per kg of paddy averaged at Nu. 48.5*(SD=13.1.* Total average cost of production per acre was Nu. 28784.2 *(SD=8065.1).* The crop data maintained at ARDC Bajo showed that the average yield was higher at 1.42 ton/acre. Using this figure, the average cost of production per kg worked out to Nu. 20.56 Per kg. The difference in the cost of production is mainly attributed to difference in yield, which was noted to be quite low in the current study (extremely low in few cases due to bird attack problem). The net returns

to land is Nu.3039.8 *(SD=20959.3)* per acre. If not for spring rice, farmers leave the land fallow from Feb-June (spring rice duration), hence the net returns to land is justifiable. However, the net returns to labour is Nu.400.5 *(SD=343.5),* which is below the prevailing wage rate of Nu. 450 per day. Net returns to household labour per acre is Nu. 23007.3 *(SD=21321.1*). The lower net returns to labour indicates that spring rice cultivation is economically inefficient unless farmers have adequate household labour available.

Table 3. Production costs and net returns

Labour costs variation	Total costs (Nu)	Standard Deviation
Labour costs for Nursery (Nu /acre)	1774.4	669.6
Labour costs (main field Nu /acre)	18193.1	6136.0
Total labour costs (Nu /acre)	19967.5	3402.8
Total costs (Nu/acre)	28784.2	8065.1
Total production (Kg/acre)	646.5	269.3
Costs of production (Nu/Kg)	48.5	13.1
Net returns to land (Nu/acre)	3039.8	20881.0
Net returns to all HH labour (Nu/acre)	23007.3	21321.1
Net returns to labour (Nu/person)	400.5	344.1

3.7. Qualitative analysis

3.7.1. Reasons for spring rice cultivation

The rate of technology adoption and its success is dependent on the users intentions behind the adoption of the technology (Mathieson, 1991). The study aimed to get a glimpse of the farmers' motive behind the adoption of the spring rice. As shown in Figure 5, the study revealed that 57% of respondents (25 HH) cultivated spring rice for household food self-sufficiency and for earning extra income from the sale of surplus amount, while 27% of respondents (12 HH) cultivated spring paddy due to the availability of government subsidy. According to the assessment, government's subsidy of free inputs such as seed, fertilizers and polythene sheet have become an encouraging factor for adopting spring rice. A total of 14% of respondents 6 HH) cultivated spring paddy due to the sheer influence of their previous Gup, who had an influential personality in the community. Some 2% of the respondents expressed that they cultivated the crop as all their neighbours were cultivating. Loss of yield to bird attack is one of the major reasons behind farmer's lack of interest in spring paddy. Others factors such as lack of household labour and already food self-sufficient also contributed to farmers decreasing interest in spring rice.

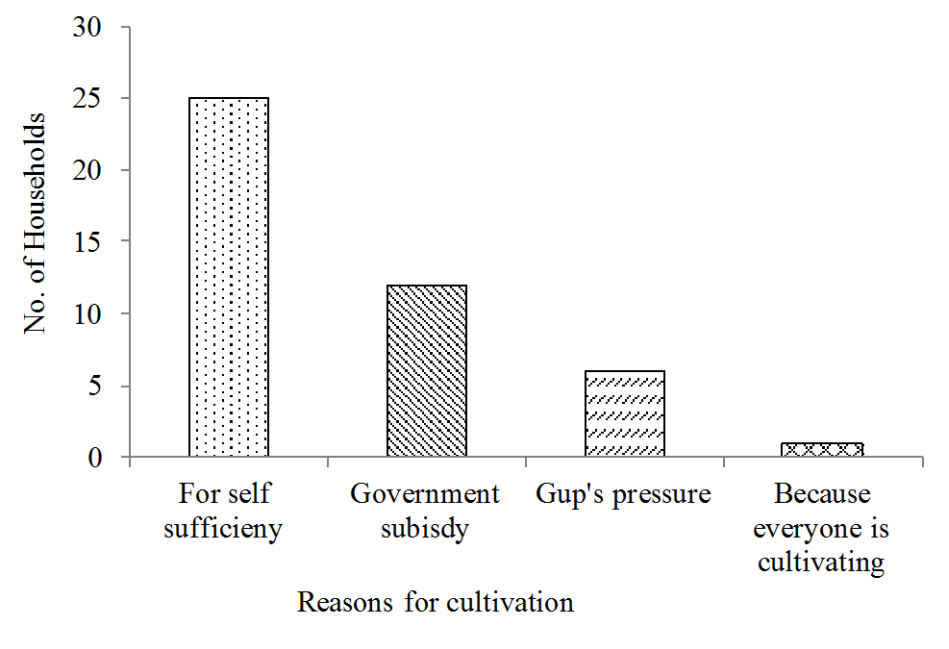

Figure 5. Reasons for spring rice cultivation

3.7.2. Major issues with spring rice

The results from the study revealed three major issues with regards to spring rice cultivation: bird attack, labour shortage and low productivity. These three factors were also identified as the main reasons behind the decreasing spring rice area in the community. Bird attack stood out to be the most prominent issue faced by all the growers. According to the growers, the incidence of the bird attack is increasing over the years. According to Subramanya (1994) foraging by bird pest in crops is dependent on the presence of favourable habitations with predator avoidance behaviour. The second issue of low yield (expressed by 8 HHs) is interlinked to first issue of bird attack. Low yield is also attributable to agronomic factors such as poor soil, poor crop management, lack of timely and proper intercultural operations, etc. The third issue of labour shortage and corresponding high labour costs (expressed by 6 HHs) is a concerning factor observed in all most all parts of the country. According to Tobgay (2005)low farm mechanization in the country is chief cause of high labour cost. Besides, the increasing rural-urban migration particularly the educated youths moving to the cities for better opportunities is creating extreme labour shortages in the rural regions (NSB 2015). As such rice is a highly labour intensive crop, and with the issues of labour unavailability and high labour costs, paddy is becoming an economically unsuitable crop for the low-income farmers.

Farm equipment and machineries make labour intensive operations easier and efficient thereby making rice production economically viable and sustainable (PhilRice 2012). The Government's initiative on the introduction of the farm machine hiring system is observed to have positive impacts in the lives of farmers. The farm machinery hiring services has also resulted in recultivating lands that were previously left fallow due to labour shortage. However, the current hiring system is faced with many challenges such as lack of trained

operator, frequent break-down of machines with no repair services on time and lack of enough machines affecting timely availability that often leads to disputes and conflicts.

3.8. Sensitivity analysis

A sensitivity analysis was conducted to assess the effect of a change in labour and material costs on the cost of production.

3.8.1. *Change in labour costs*

When the labour cost is valued at 100%, the cost of production is Nu.48.5 per kg of paddy. The opportunity cost of all household labour is 75% of the total labour cost. Hence, if the price of all labour is valued at 75% of the hired labour price, the cost of production drops from Nu 48.5 to Nu 35.3 per kg paddy, showing a drop of 27.2%. Correspondingly, the net returns to land, labour (per day) and all households labour increases as shown in Table 3.If the price of labour is further decreased to 50% of the hired labour costs, the cost of production further drops to Nu 29.1 per kg showing a drop of 40%. The net returns to land, labour (per day) and all households labour increases as depicted in Table 3.

Table 3. Costs of production at varying labour costs

Labour costs variation	Real price	at 57% of hired labour cost	at 50% of hired labour cost
Labour costs for Nursery (Nu/ac)	1774.4	1242.1	887.2
Labour costs for main field (Nu/acre)	18193.1	12735.2	9096.6
Total labourcosts (Nu/acre)	19967.5	13977.2	9983.7
Total costs (Nu/acre)	28784.2	22794.0	18800.5
Total production (Kg/acre)	646.5	646.5	646.5
Costs of production (Nu/Kg)	48.5	35.3	29.1
Net returns to land (Nu/acre)	3039.8	9113.7	23007.3
Net returns to all HH labour (Nu/acre)	23007.3	28997.5	32991.0
Net returns to labour (Nu/person)	400.5	505.7	575.9

3.8.2. Change in material costs

Under the current production system, government supplies free inputs such as seeds, fertilizers and polythene sheets, which constitute 37% of the total material costs (13% for seed, 15% for fertilizers and 9% for polythene sheet). Thus, if a reduction of 37% in the material costs is considered, the cost of production per kg of paddy will decrease by 18.6% to Nu. 39.5. Subsequently, net returns to land, labour (per day) and all household labour increases as shown in Table 4.

Table 4. Cost of production at 37% reduction in input costs

Input costs variation	-37.0	At Real price
Total input costs	5554.5	8816.7
Total costs (Nu/acre)	25522.0	28784.2
Total production (Kg/acre)	646.5	646.5
Costs of production (Nu/Kg)	39.5	48.5
Net return to land (Nu/acre)	9564.2	3039.8
Net returns to all HH labour (Nu/acre)	29531.7	23007.3
Net returns to labour (Nu/person)	522.8	400.5

4. Conclusion

The results from this study showed that on an average 45 labour days per acre is used for growing spring rice with over 45% of the labour use accounted for planting, weeding, harvesting and transportation of FYM. While farm mechanization has picked up over the last few years (particularly use of power tillers and threshers), there are still large opportunities to be explored in the areas of planting, harvesting and weeding.

The market price of paddy is Nu 32.3 per kg which is lower than the average production costs of Nu 48.5 per kg. The high production cost above the market price makes spring paddy economically unviable for the growers. The high cost is mainly attributed to low yield due to bird attack problem and high labour costs. Thus, the enhancement of area under spring rice calls for the development of a bird control device/mechanism or a bird-free production strategy. Research in the areas of bird pest management and development of bird repellent rice varieties needs to be done. The other area of focus would be farm mechanization to help bring down the labour costs in the farming operations.

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Cost analysis of operating a medium sized rice processing mill in Bhutan

Kinga Norbu[q]

ABSTRACT

The study aimed to ascertain the cost of operating a medium sized rice mill in the country. The fixed cost and variable cost were calculated for operating the rice mill. An empirical formula was derived to forecast the revenue generated while running the operation. The moisture content of paddy during purchase may not greatly influence the profit margin as the loss is not significant when the quantity is huge. The rice milling recovery at 67% indicated satisfactory performance of the mill; remaining 33% consisted of husk, bran and the broken grains. Hence it is important to ascertain alternative use of the by-products which also add up to the profit. There is a significant difference between the cost of milling with subsidy from the government, or investment in rice mill and infrastructure and also with rental charge on these facilities. Still it is a good business to own and run a rice mill.

Keywords: *Cost of operating; rice mill; milling recovery*

1. Introduction

The government is promoting medium sized rice processing machines in rice growing Dzongkhags in the country under the Accelerating Bhutan Socio Economic Development programme. The objective behind the initiative is to have good processed and packaged rice for sale in the domestic market. The government is also equally implementing programmes such as increasing irrigation network and farm mechanization programme which will lead to more area under cultivation and thus increasing the paddy production in the country. With high yielding varieties, the scope for increased production is high which is intended to reduce import of rice in the country.

The rice processing machine however needs investment which includes both infrastructure and the installation of the plant. It also requires paddy storage, the drying area and the milled rice storage. The storage houses also require controlled temperature to protect it from insect infestation and reduce mould formation, which however is not included in the government initiative at present. The government has invested in the construction of the infrastructure and purchase, installation of the rice mill at different places. The proposal is to hand over the operation to Food Corporation of Bhutan initially and then hand over to the private sector. Hence this study will ascertain the cost analysis of operating such rice mills.

2. Materials and Methods

The cost of construction and installation of the rice milling machine was Nu 1.9 m and cost of rice mill was 2.04 m (DoA tender document). The fixed cost and variable cost have been calculated (Kinga 2013) as described below. The fixed cost includes depreciation cost**,**

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interest on investment and insurance cost. The variable cost includes electricity cost**,** labour wages and repair and maintenance cost**.**

i) Depreciation cost: According to Kepner et al (2005), the annual depreciation was calculated as

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

Where D= Yearly depreciation; P= Purchase price of the machine (Nu), S= is the salvage value or the selling price of the machine after its useful use (Nu) and assumed as 10 % of the machine price; L= useful life of the rice mill between buying and selling (10 years for farm machinery).

ii) Interest on investment: In Bhutan, the maximum interest generated through fixed deposit is 4%. According to the Kepner et al (2005) and Khairo et al (2009) the annual interest on the investment was calculated as follows:

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

where, I= Rate of interest in %, i= Annual interest rate for buying a rice mil

iii) Insurance and taxes: It is amount spent on insurance every year as this rice mill.

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

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

Calculation of variable cost of the rice mill

i) Electricity Cost
It is calculated as the total KW x number of operating days x the rate (BPC)

ii) Repair and maintenance cost
According to Kepner et al (2005) it was taken 2.5% of the purchase price. However for Bhutanese terrain, it was proposed 8% as the repair needed is frequent.
RM = 8% x purchase price of farm machinery (Nu)

iii) Operator and labour wages

Labour cost = Nu 7000 /head/month x 12 months x 4 person

Mathematical analysis

i) Cost of operation is the cost involved in the operation of the rice mill

$$CoO = \frac{Total\ Annual\ Cost\ (\frac{Nu}{year})}{Capacity\ of\ the\ machine\ (\frac{acre}{year})}$$

where total annual cost includes both fixed cost and variable cost. The capacity of the machines is its performed capacity in acre/year

The cost of milling has been calculated based on three categories:

a. The initial investment as zero as the both the construction and purchase are done by the government

b. The initial investment calculated on rental basis at 10%, 20& and 30% respectively
c. The initial investment included as if it is operated by private without any government support.

The rice milling recovery was considered at 67% from the paddy as 20-22% includes the husk and remaining included in the polishing. The cost of purchased paddy is taken at Nu 30/kg and the selling of the rice in the market is assumed at Nu 70/ kg as surveyed from the farmers. The moisture content of the paddy at purchase time is assumed at 22%.

The change in weight because of the variation in the moisture content is calculated through this equation (Kinga 2012)

$$Water(X) = W - W \times \left\{\frac{100-MC_i}{100-MC_f}\right\}$$

Where W is the weight of the rough rice in gram, MC_i is the initial moisture content in decimal, X is the amount of water to be added to removed in gram, and MC_f is the final moisture content in decimal.

3. Results and Discussion

3.1. Paddy weight variation with change in moisture content

The weight of the paddy is directly influenced by the moisture content of the paddy. The moisture content during the purchase is assumed to be at 20%, whereas at harvest it normally ranges from 22-24%. At the milling time, it is important that the moisture content is in the range of 11-13% to ensure less breakage during the milling process. This change in moisture content from 22% or 18% to 13% reduces the overall weight of the paddy which is a loss as shown in Figure 1.

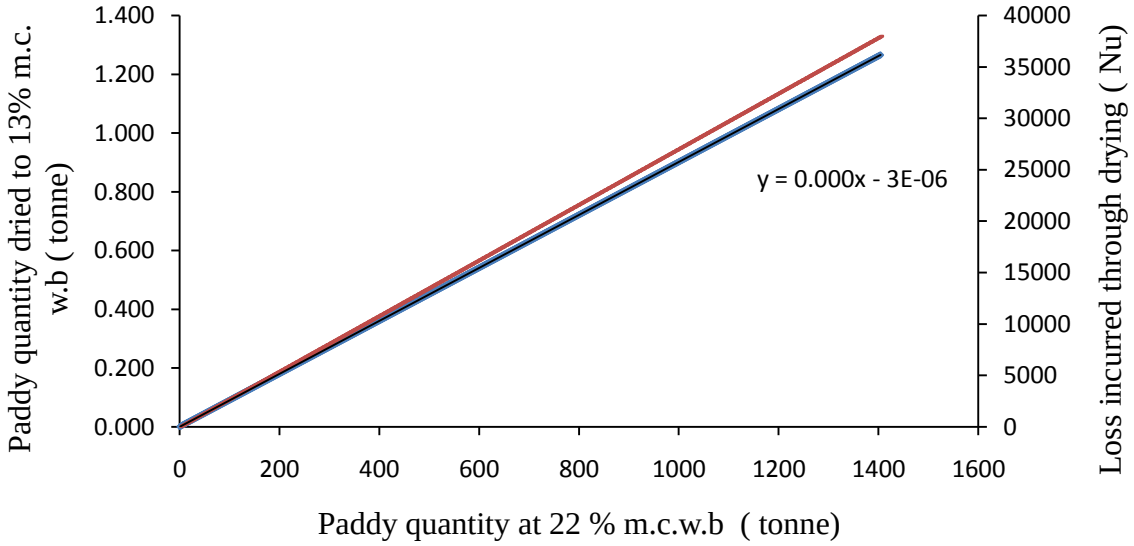

Figure 1. Paddy weight variation through drying and cost incurred

Even at 22% moisture content when the paddy is purchased from the farmers' fields, the loss incurred in paddy weight after drying to 13% for milling was 1.2 ton when quantity of paddy

purchased is around 1400 tonnes. The loss amount incurred was Nu 36000 for this quantity which may be negligible. Hence, concern on the moisture content during purchase of paddy should not be a prominent issue.

3.2. Rice milling recovery

During the milling process, the paddy has to be converted into rice. The rice milling recovery is assumed to be 67%. The remaining consists of the husk and the bran. Figure 2 shows the amount of milled rice and paddy during the milling process.

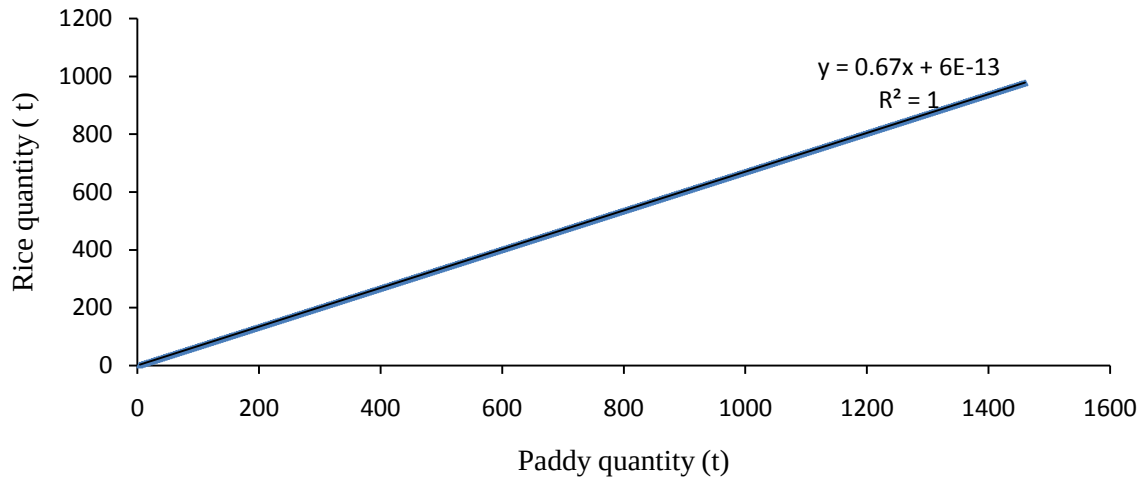

Figure 2. Rice and paddy quantity relationship

However this trend is assumed under the condition that the moisture content of the paddy is around 13% which is required for milling. It gives a very clear picture and indication of how much rice can be collected once the milling operation is completed. The quantity of rice collected is always lower than the initial paddy quantity as the remaining loss consists of husk, bran, brokens etc. The rice collected was 630 tonnes for every 1000 tonnes of paddy milled.

3.3. Cost analysis between paddy purchase and rice sold

Figure 3 shows the relationship between the quantity of paddy processed and revenue generated from the sale of rice. More the rice processed wider will the difference between the two lines in the graph which is better for the firm.

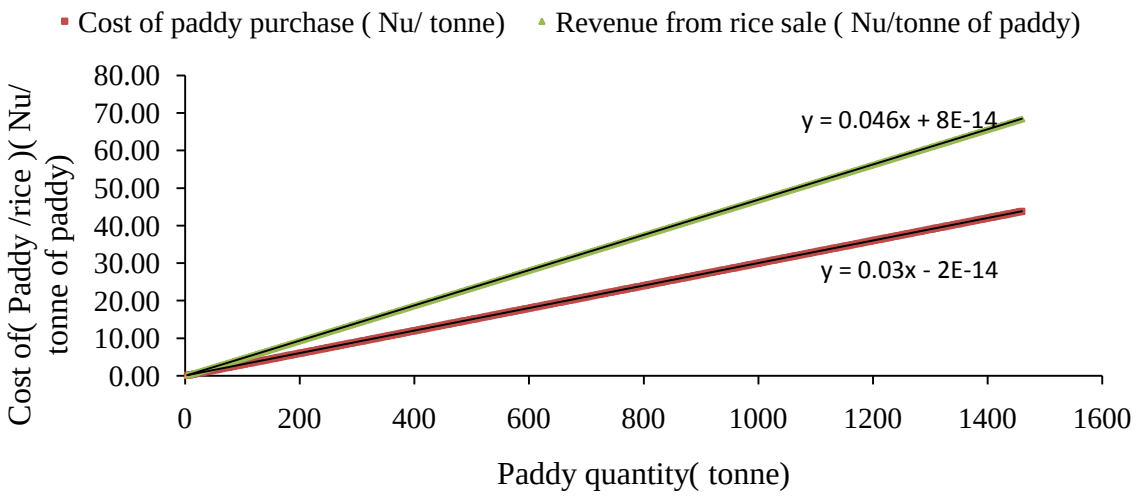

Figure 3. The prevailing paddy cost and rice price (Nu/tonne)

The difference is the amount that includes loss/profit, the milling cost, transportation, packaging and selling of rice. When 500 tonnes of paddy is purchased, it will cost Nu 15 m and this amount when processed and sold will fetch Nu 23.45 m. When 1000 tonnes of paddy is purchased it will cost Nu 30 m and when processed and sold will fetch Nu. 46.9 m. This is at the prevailing rates of the farmers. This shows that when the paddy quantity is increased, the revenue made will also increase as indicated in Figure 3.

3.4. Cost of milling

The cost of milling paddy into rice is the major operation with other operations also equally important in the entire operation. The cost of milling per tonne with this level of investment on plant and infrastructure is shown in Figure 4. It also includes if rental is charged at 10-30% to the mill users when investment is from the government.

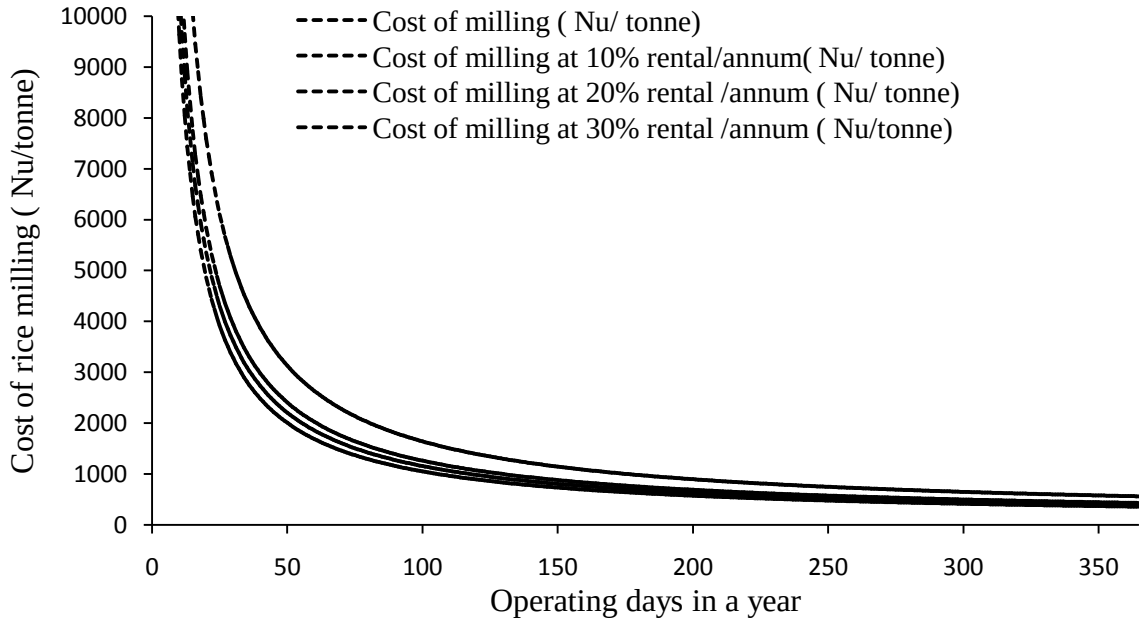

Figure 4: The cost of milling (Nu/ton) with operating days

It is clearly shown that if milling cost/ton is to be brought to Nu. 1000/ton, then the operating days should be 105 days with investment, 118 days with 10% rental per annum, 130 days with 20% rental per annum and 176 days with 30% rental per annum for using the mill and the infrastructure.

However, if the cost of milling is to be brought to and less than Nu 2/kg, then the operating days should be 50 days, 55days, 61 days and 80 days respectively with respect to the rental charge percentages. It can be clearly seen that with increasing operating days, the cost of milling can be reduced further which is good for the business as shown in Figure 5.

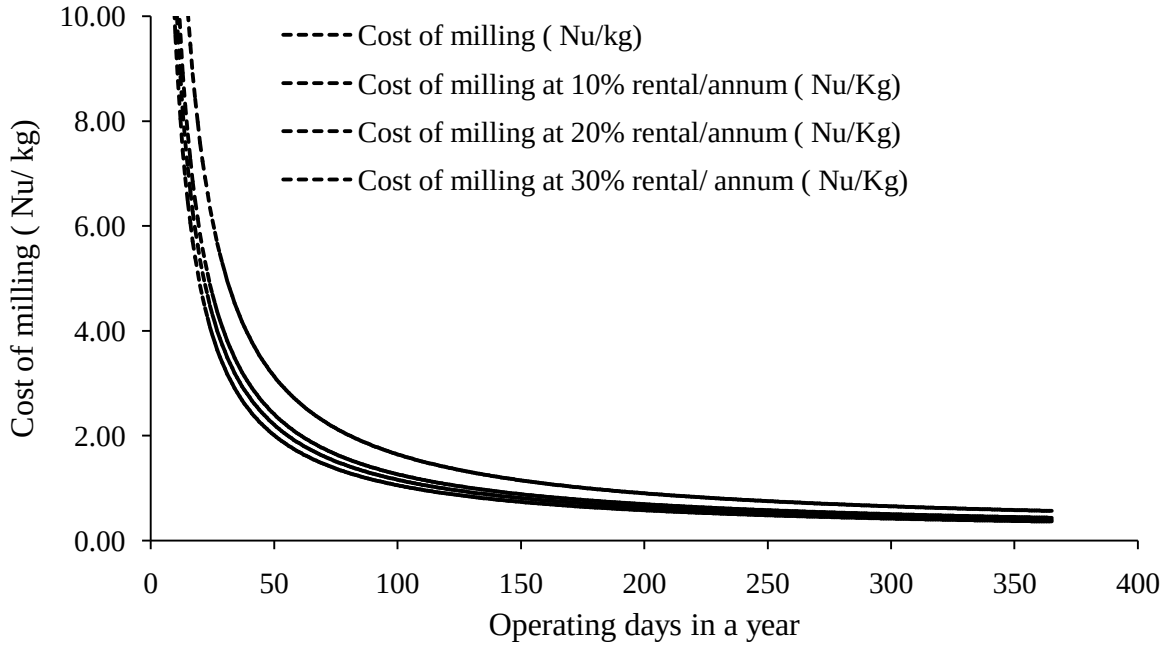

Figure 5. The cost of milling (Nu/kg) with operating days

In case the government decides to let the FCB or any firm operate it without any rental charge or investment on the plant and the infrastructure as subsidy, the cost of milling will be further reduced as shown in Figure 6.

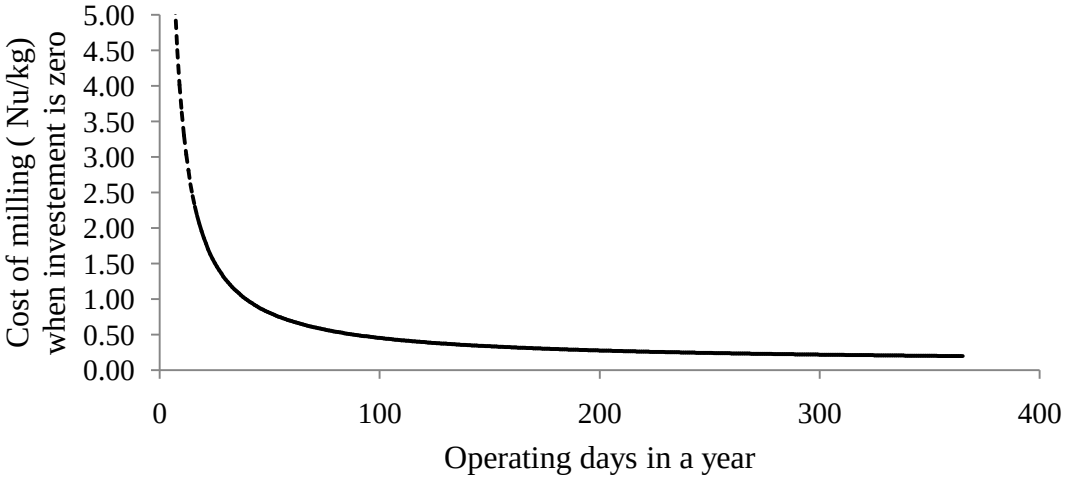

Figure 6: The cost of milling with subsidy with both rice mill and infrastructure

It can be seen that the cost of milling is further lowered. The milling cost will be only Nu 0.5 per kg if the mill is operated in full capacity for 88 days or about 3 months.

3.5. Revenue Generation

An empirical formula can be used to forecast the revenue generated from all the figures and assumptions stated above:

$$Revenue\ generated\ (M) = (0.07 \times 0.67X - \{[0.03\ \times X] + [0.002 \times X]\})$$

Where X is the paddy quantity (ton)

4. Conclusion and Recommendation

Some interesting observations through this study and analysis of the data are summarized. The moisture content of the paddy during purchase may not greatly influence the profit margin as the loss amount is not so significant when the paddy quantity is huge. However, the drying process may prolong and add up to unnecessary expenditure. The rice milling recovery at 67% indicates that the remaining 33% which consists of husk, bran and the broken as loss. Hence it is important to ascertain alternative use of these by products which also could fetch money. If the quantity of paddy purchased is higher, the revenue made is also higher when processed and rice is sold. Hence it will always be profitable if the paddy quantity is increased when other factors like spoilage and optimum storage conditions are addressed. There is a difference between the cost of milling with subsidy from the government, or investment in rice mill and infrastructure and also with rental charge on these facilities. Still it is a good business to own and run a rice mill.

Acknowledgment

The author would like to thank the Farm mechanization specialist for providing the cost of the rice mill and the infrastructure and also for suggestions on the economics of the rice mill.

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Assessment of Community-Based Maize Seed Production in Eastern Bhutan

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ABSTRACT

Community-Based Seed Production (CBSP) in Bhutan was first initiated in 2006 to overcome and address maize seed degeneration and rapid multiplication of Grey Leaf Spot tolerant varieties. With the success stories of the CBSP model in the first initiated groups, the CBSP concept has been replicated in various other maize growing areas. This study was carried out in one CBSP group each from four eastern districts namely Mongar, Lhuentse, Tashiyangtse and Tashigang. A total of 121 CBSP members were interviewed using semi-structured questionnaires. The main aim of this study was to assess and document the impacts of CBSPs and evaluate seed production trend within the community. The introduction of CBSP in the community saw an increasing trend of seed production in the last six years (2011-2016).The study found that the total production of maize in the four study sites increased by 45.4% from 37.4 ton in 2011 to 139.3 ton in 2016. The initiation of CBSP helped in improving food self-sufficiency within the community through increased productivity. The result from this study showed that more than 96.7% of the respondents became food self-sufficient. The study also found that mobilization of CBSP group brought unity within the community. Besides, the introduction of CBSP also helped in increasing income; the income increased by 54% in the last five years (2012-2016). The study also reported that the initiation of CBSP has benefited in ensuring seed security and quality seed production at farm level. This study also noted some negative impact such as loss of traditional varieties and increasing wage rate with the establishment of the CBSP model.

Keywords: *Community-Based Seed Production; seed quality; seed security; household Income; Food self- sufficiency*

1. Introduction

Maize is one of the most widely cultivated food crops in Bhutan. More than 69% of the rural households across the 20 districts grow maize on 61,403 ac land (DoA 2015). It is a major food crop cultivated widely in the six eastern districts accounting for up to 46% of the total maize area and over 54% of the total production (DoA 2015). The total production and the national average yield are 74,370 ton and 1.224 ton/ac (DoA 2015). Being ranked as first in the extent of area cultivated, it plays a vital role in ensuring the household food security. According to Katwal et al (2007), about 80% of the total production is consumed at the household level by the farmer which is valued at Nu. 353 million annually. Only 6% of the total production is sold, which is an important source of household income (Katwal et al 2015).

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Bhutanese farmers grow different maize varieties in same field or in close proximity due to limited size of land holding which had lead to the production of undesirable seeds. Most of the farmers meet their seed requirement from informal traditional seed system managed by themselves from their farm saved seed which has lead to poor quality seed. Maize seed degeneration was underpinned to the lack of poor seed source and production practice. Moreover, in 2007, a major fungal disease called Gray Leaf Spot (GLS) which was never reported before in the country seriously affected 12 major maize growing districts which prompted seed replacement initiative (Katwal et al 2015). The introduction of CBSP in maize seed system had played a vital role in producing improved quality seed and fulfilling the demand of the increasing populace besides being replacing degenerated poor seed. CBSP was initiated to overcome and address seed degeneration and rapid production of GLS tolerant varieties (Katwal et al 2009). In order to rapidly produce GLS tolerant seeds and to address the seed degeneration problem, the National Maize Program (NMP) based at Agriculture Research and Development Centre (ARDC) Wengkhar initiated an approach called Community-Based Seed Production (CBSP) in 2006, which was emulated from the hills of Nepal. With the success stories of the CBSP models in the first initiated CBSP groups in Waichur and Shaphangma in Mongar, the CBSP model had been replicated in various maize growing areas. Currently there are 11 CBSPs spread in seven districts, including, Mongar, Lhuentse, Tashigang and Tashiyangtse in the east. Across the nation, about 80% of the seed replacement after the GLS outbreak has been accomplished through CBSP groups (Katwal et al 2015).

As per Katwal et al (2015) CBSP has several other advantages such as access to quality seeds, income generation through the sale of maize, adoption of improved technologies and free input supplies. CBSP initiation in the country has been more than a decade old; however there have been no studies to determine and document the impacts of the CBSP seed production model in maize. Thus, this study will quantify the impacts and study the maize seed production trend after the initiation of CBSP. The results from this study will therefore determine the scope for replication of such model in other major maize growing area. The primary objectives of the study are to document and assess maize seed production trends through the adoption of Community-Based Seed Production model and to document the economic and social impacts of CBSPs on Community.

2. Materials and methods

2.1. Description of the study area

The study was conducted in four eastern districts of Bhutan namely Mongar, Tashigang, Lhuentse and Tashiyangtse where CBSP groups in maize promoted or adopted. In each of these districts one CBSP group was randomly selected. The sample CBSP groups of Mongar and Tashigang districts represent older groups which are more than five years old and those of Lhuentse and Tashiyangtse represent new groups which are less than five years old. The four group selected in are Waichur in Mongar, Budur-Kupeneysa in Lhuentse, Changmey in Tashigang and Sharli in Tashiyangtse. The sites share a similar type of climatic condition; hot and wet summer to dry and cold winter. The annual average temperature for all the four sites

ranges from 16° to 23°C and annual rainfall ranges from 1,000 to 1,500 mm (NSB 2012). The study sites lie at an elevation ranging within 500 to 2000 masl.

2.2. Sample size

From a total of 173 households (Table 1) of four randomly selected CBSPs in the four eastern districts, 121 respondents were determined using the Yamane formula: $n = \frac{N}{1+Ne^2}$. The formula has 95% confidence interval and 5% error level. A simple random sampling technique was used to carry out the sampling. The 121 CBSP members were further distributed into their respective groups (Table 1). The sample size from each CBSP group was calculated and simplicity non-probability sampling was used to select the respondent from each group with the help of geog extension, ARDC researchers and geog administration. Sample size was calculated as:

Sample size from each CBSP group = $\frac{\text{Household of each group x Total sample size (n)}}{\text{Sampling frame (population)}}$

Table 1.Maize cultivation and production in the four CBSP sites

Dzongkhag	CBSP group	No. of household	Sample size
Mongar	Waichur	20	14
Lhuentse	Budur-Kupeneysa	57	40
Tarshigang	Changmey	53	37
Tashiyangtse	Sharli	43	30
Total		173	121

2.3. Data Collection and analysis

The data was collected through individual interview using a semi-structured questionnaire and informal group discussions. The primary data was supplemented with secondary data from relevant journals, online resources, RNR statistical records and other relevant documents. Some of the important interview questions included social and economic impacts of CBSP, benefits of CBSP in the community, annual production of maize, food self-sufficiency. The data collected was analyzed through Microsoft Excel and Statistical Package for the Social Sciences (SPSS Version 20). The data were checked for normality and homogeneity of variance using Shapiro-Wilk's and Levene's test. The data were analyzed using both descriptive and inferential statistics; mean frequencies, percentages, minimum and maximum value, mean, standard deviation and standard error of different numerical and categorical data. A paired sample *t*-test was carried out for comparison between two variables.

3. Result and discussion

3.1. Land Utilization in the CBSP study sites

Most members of the CBSPs are small-scale farmers who are dependent upon agriculture. Every member in the four sites utilizes about an average of 1(±0.6 acre) of dry land and 0.6 (±0.8 ac) of wet land (Table 2). From 193 ac of total dry land only 112 ac is under cultivation and similarly from the total 49.9 ac of wet land only 37.9 ac is cultivated, the remaining lands being fallow. The CBSP group in Lhuentse had the highest maize cultivation area with 37.08 ac, which is mainly due to more number of CBSP household in the community. The group in Mongar had the least with 18.14 ac since the group had fewer members. The main reasons cited for keeping the land fallow are labor shortage and wild animal damage.

Table 2. Land utilization in the study sites

	Total (ac)	Average (SD)
Dry land	193	1.6 ± 2.0
Cultivated dry land	112	1.0 ± 0.6
Wet land	49.9	0.7 ± 0.9
Cultivated wet land	37.9	0.6 ± 0.8

3.2. Maize Production Before and After CBSP

The production in terms of output per area under cultivation was low when compared to current situation. The average maize yield before the establishment of CBSP was 1 ton/ac and it has increased to 1.2 ton/ac (Figure 2). A paired sample *t*-test was carried out to compare the yield before and after the initiation of CBSP. There was a significant difference ($p<.05$) in the yield before (1.0± 0.48 ton) and after (1.2 ± 0.55 ton) condition at; t (120) = -10.9, p=0.001). It indicated that with the assured quality seed, the yield had increased after the CBSP establishment.

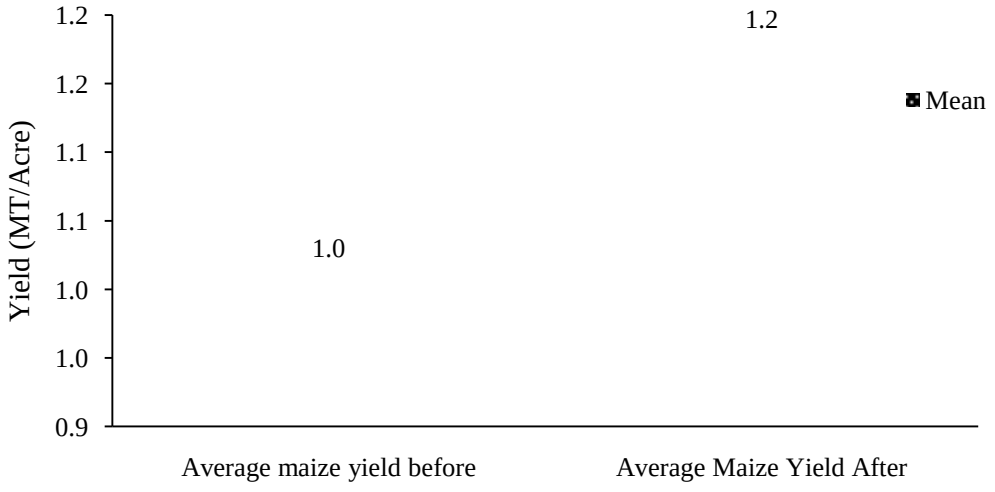

Figure 2. Maize yield before and after CBSP initiation

The reduced performance in the past was mostly attributed by factors such as crop losses to wild animals, maize disease such as GLS, growing of different maize varieties on a same patch of land and non-use of high yielding improved varieties. People were not aware of seed degeneration problem, nor did they receive any training related to maize cultivation. However, with the initiation of CBSP, the farmers are exposed to quality maize production through capacity development such as field day, training on seed production and selection, out-country study visit etc. which has helped in production of maize. The supply of high quality source seed has also contributed in high productivity after the initiation of CBSP. Moreover, with the installation of electric fencing in some of the study sites, the problem of crop depredation by wildlife has declined resulting in higher productivity.

Upadhyaya et al (2014) compared the production capacity of CBSP farmers and non-CBSP farmers in the hills of Nepal. The study reported that the production of CBSP farmers was 0.8 ton/ac and 0.62 ton/ac for non-CBSP farmers. The difference of 13.3% was found between the CBSP and non-CBSP in terms of maize production.

3.3. Seed Production Trend

The area, production and productivity of maize are slowly increasing. Today with the increase in numbers of CBSP group, the area for maize cultivation is expanding and the production is increasing. Figure 3 shows the seed production trend and cultivation area for six years. The study found that the production of maize has increased from 37.4 ton in 2011 to 139.2 ton in 2016. The area for cultivation of maize remained constant till 2014 at 39 ac and in 2015 with the establishment of two new groups, the area has increased to 112 ac. Maize productivity has increased due to adoption of quality seed production concept. The community grows the most preferred variety with higher production.

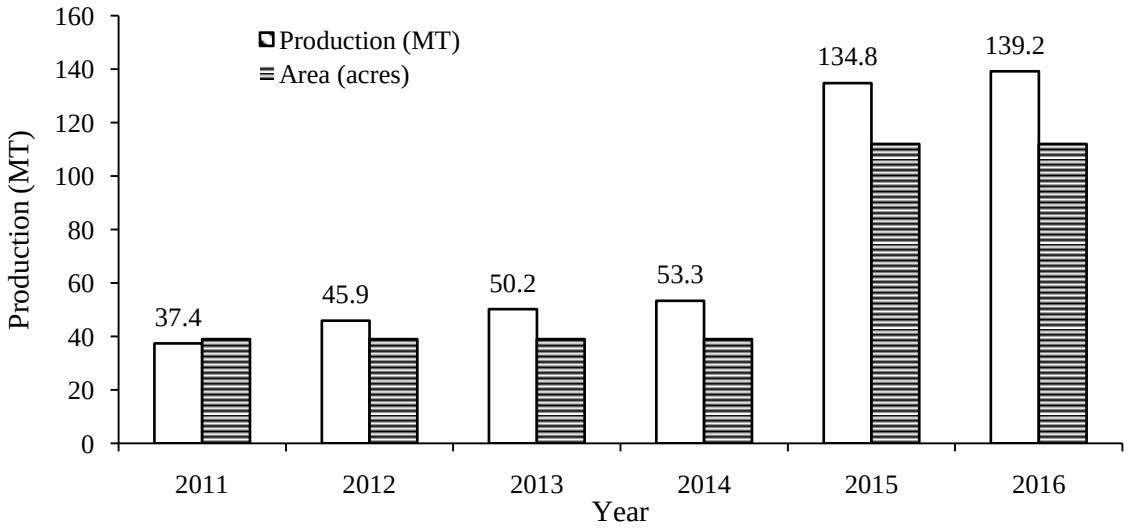

Figure 3. Annual seed production trend

A similar result was observed from an evaluation study in the CBSP sites of Nepal. Upadhyaya et al (2014) reported that the rate of improved seed production through CBSP had

increased by several folds from 14 ton in year 2000 to 830 ton in 2010. The study showed that CBSP brought a considerable increase in the production of maize seed over the years.

3.4. Social Impacts of Community-Based Seed Production

3.4.1. Unity within the Community

According to the findings from this study, the initiation of CBSP has played a role in building and enhancing unity within the community. Out of 121 respondents, more than 14% of the respondents agreed that the initiation of CBSP has brought unity in the community, while 28% of the respondents hardly agreed with it. CBSP requires a willing community and without unity in the community, those CBSP would not have been established, thus the respondents felt that unity had been there before the initiation of the group. However, majority (38.7%) of the respondents slightly agreed on unity being created by CBSP initiation. Those respondents felt that after the initiation of the group, the communities started helping each other especially in terms of labor. A study by Mathema and Gurung (2006) reported that the group formation and mobilization as one of the most successful steps to bring in unity among the community. Renuka et al (2015) described the initiation of community seed bank as one tool which had brought unity in terms of decision making within the community in Mahabubnagar village of Telangana State in India. The approach of group formation and mobilization has added the value for sustainability of the CBSP (CIMMYT 2015).

3.4.2. Free Input supply and Technical Support

Table 3 shows the relevancy of free input supplies and technical support brought in by CBSP. The number of the respondent saying the free input supply as a relevant positive change brought in by CBSP was 41.1%. Not a single respondent said that it was not relevant. Only 12.2% of respondents felt technical support as the most relevant impact that came with the initiation of the CBSP.

Table 3. Percentage (%) of the respondents on impacts on free input supplies and technical support

Relevancy of the Impact	Free Input supplies	Technical Support
Less	6.5	23
Slightly	27.2	43.2
Relevant	41.1	21.6
Most	25.2	12.2
Total	100	100

Today, CBSP groups are provided with free input supply such as foundation seed at the initial year of establishment and after every two years. The CBSP groups are also provided with cornflake machine, Tengma frying pan, portable corn sheller, hoe and sickle and chemical fertilizers. The technical support such as training on quality seed production, seed selection, and pest and disease management are frequently provided. A regular monitoring on seed

production is done by both researchers and extension. Wangdi and Wangchuk (2015) reported that CBSP farmers are provided with three types of training at various intervals of maize growing stages which have contributed in quality seed production. The introduction of CBSP in the hills of Nepal has benefited the farmers with various training related to quality seed production and free input supplies as reported by Mathema and Gurung (2009).

3.5. Impact on Seed Security and Quality Maize Seed production

More than 30% of the respondents (Table 4) reported seed security and quality production as the most important positive impact that came with the establishment of CBSP. In the past, the community used to grow different maize varieties in same field or in close proximity due to limited size of land holding which had lead to the production of undesirable seeds. However, after the start of CBSP, farmers now grow the same variety of maize to avoid crossing. The farmers are also provided with many other inputs in the form of technical support by which the quality of seed production and seed security has improved significantly. Katwal et al (2009) reported that unlike other cereals, maize being cross-pollinated causes seed degeneration and the entire members of the group are encouraged to grow the same variety to avoid out-crossing, thus resulting in good quality seeds. The researchers in collaboration with the extension staff train all the CBSP members on production of quality seed, thus promoting seed security (Katwal et al 2009). Mathema and Gurung (2006) reported that the initiation of CBSP had enhanced quality and increase in maize seed production.

Table 4. Percentage (%) of respondents on impact on seed production and security

Degree of Impact	Quality Seed Production	Seed Security
Not Important	1	6
Less Important	26	24
Important	38.5	37
Most Important	34.5	33
Total	100	100

3.6. Change in Food consumption pattern in the CBSP Community

The food consumption pattern has also changed with the establishment of CBSP group. The percentage of respondent consuming maize before the initiation of CBSP was 95.9%, rice was 2.5% and millet was 1.7% (Figure 4). After the initiation of CBSP the percentage of maize consumption has decreased to 16.5% and the consumption of rice has increased to 83.5%. A paired sample t-test was carried out to see the differences. The study shows a significant ($p<0.05$) difference in food consumption pattern before (1.05±0.29) and after (31.83±0.37) condition at $t(120) = -18.7$ $p=0.001$).

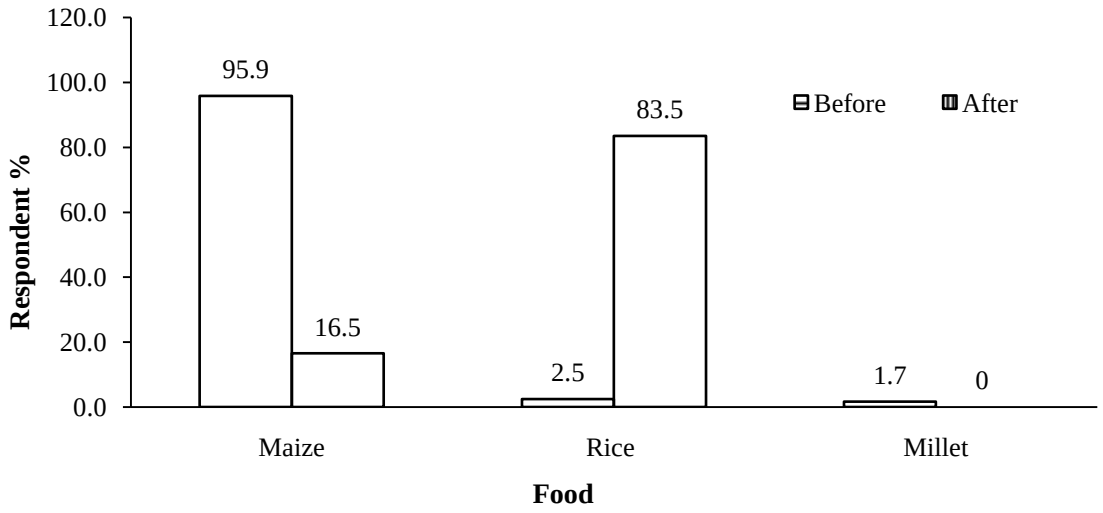

Figure 4. Change in food consumption pattern before and after the CBSP

Most of the respondents shared their views on the change of food consumption pattern. Maize always had a connotation of being a poor man's food. Maize is consumed as a staple food in the form of *Kharang* (grits) and hardly any cash is earned from the sale of maize, thus people are left with no option than to consume maize. However, today with the group formation, the marketing of maize is easy and the cash they earn from the maize has helped them to purchase and consume rice. Citing a report based on the Maize Assessment Survey 2005, Katwal et al (2015) state that the maize farmers consume 80% of the maize they produce, however, with the initiation of CBSP groups, the sale of maize has increased and the cash earned from the maize is used for buying rice, other food and animal feeds. The initiation of CBSP has brought change in the food consumption pattern within the community.

3.7. Negative Social Impacts of Community-Based Seed Production

The respondents were interviewed to identify and rank the negative impacts on the basis of importance (Table 5). About 27.3% agreed the increase in wage rate as the most important negative impact that came with the introduction of CBSP. There were 18.6% of respondents who felt the loss in diversity of maize varieties as another most important drawback of CBSP. More than 16% of the respondents viewed 'labor intensive' as one of the most important negative impacts.

Table 5.Relevancy of negative social impacts of CBSP (%)

Impacts	Not at all	Not	Neutral	Important	Most
Loss in Traditional Maize Varieties	3.5	10.5	45.3	22.1	18.6
Low Yield	5.1	35.6	42.4	8.5	8.5
Increase in wage rate		9.1	14.0	49.6	27.3
Labor Intensive		1.0	39.2	43.1	16.7

Likert Scale where 1 = Not at Important, 2 = Not Important, 3=Neutral, 4 = Important, 5 = Most Important

The production of quality maize seed requires intensive labour right from sowing till the marketing. Unlike before, the current practice of growing maize for seed is different. There

are various activities such as rogouing, tagging of selected seed and other management practices involved, thus requiring more labour. Bhutanese CBSPs are small compared to the CBSPs of Nepal where the entire district is converted into seed group and every village grows different varieties of maize. However, in Bhutan the CBSP groups are small with small landholdings, thus the groups are encouraged to practice growing only one variety of maize to avoid out crossing. In the past farmers used to grow different varieties of maize in all the four sites. Today only two varieties of maize are grown. With the outbreak of GLS in 2007, CBSPs were initiated and farmers never had the chance to grow their traditional seeds leading to loss in diversity of the maize. A study by Shrestha et al (2012) found the loss in diversity of maize continues to be alarming in the CBSP sites of Nepal since farmers go for improved variety of maize. Bhatta et al (2007) reported the loss of traditional varieties was mostly due to the replacement by new improved varieties. A study by FAO (2011) found that 74% of crops grown in South Korea in 1985 have been replaced by improved varieties in 1993. The daily wage rate has increased significantly. CBSP involves intensive labor and the non-availability of the labourers within the community has increased the demand for labour. The wage rate of the male labour has increased from Nu 215 to Nu 500; similarly for female the rate has increased from Nu 150 to Nu 300. A study by Upadhyaya et al (2014) reported similar results. The study found that the price of maize seed in the market and the prevailing wage rate have direct relationship. The increased wage rates in the entire CBSP sites are due to increase in the price of maize over time.

3.8. Economic Impacts of Community-Based Seed Production

3.8.1. Impact on household income

Maize is considered as a major food crop for the farmers involved in Community Based Seed Production. It is one of the main field crops sold by the group and is considered as a major source of income (64.5%) followed by livestock product and off-farm activities such as weaving and carpentry at 12.4% respectively. Figure 5 shows the income trend from the sale of maize seed from 2012-2016. The study found that in the last five years the total income of the CBSPs from the sale of maize was Nu 40 million (M). The income trend has increased by 54% from Nu 4 M in 2012 to Nu 14.8 M in 2016. However, it showed a decrease from Nu 5.3 M to Nu 3.2 M in 2014. This was due to severe drought condition in CBSP site of Waichur in Mongar, which led to poor seed quality and low production. The average minimum income at household level was Nu 200 and the maximum was Nu 66,000 from the sale of maize. The income earned from the sale of maize was utilized in education of children, household expenses, ritual purposes etc.

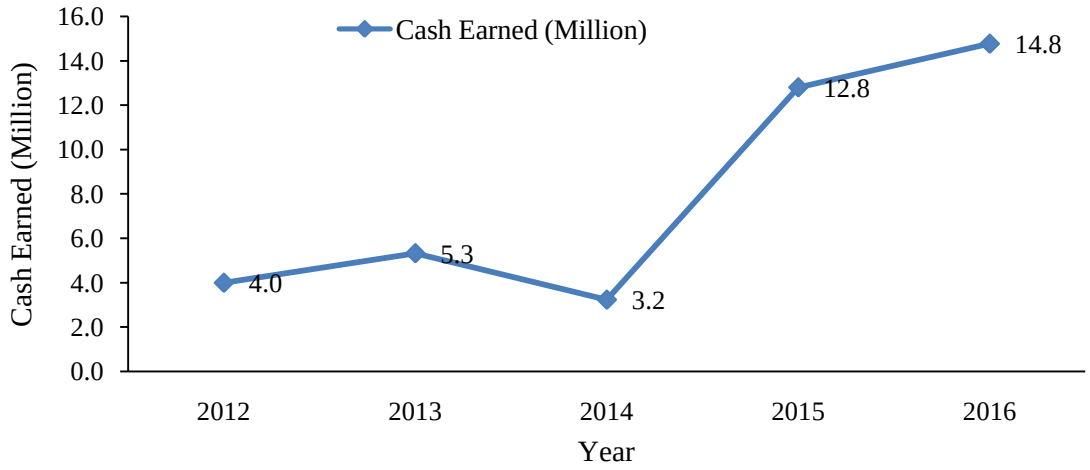

Figure 5. Income trend for six years

A study on *Maize Commodity Chain Analysis* by Katwal et al (2007) reported the sale of maize seed as a recent trend in Bhutan. Before, there were only insignificant transactions among the farmers within and outside the communities either for payment of labor or for seed. However, the CBSP has changed that trend and today all the members of the CBSP market their seeds. Upadhyaya et al (2014) reported that 86% of the CBSP members of Nepal reported an increase in maize income over the years.

3.8.2. Impact on Food Self-Sufficiency

This study looked at the household food security only from the production of maize. Since maize is the main crop grown within the community, the availability of the food is sufficient to feed the household members. About 96.7% responded that the production of maize is enough for them, however, only 3.3% of respondents felt the production of maize is not enough for their household (Table 6). These respondents had less land and labour. With the establishment of CBSP, the community grows high yielding varieties resistant to GLS, thus the food produced is sufficient.

Table 6. Respondent of maize self sufficiency

Maize Production	Respondents' (%)
Enough	96.7%
Not Enough	3.3%
Total	100%

This study also found changes in the food self-sufficiency status before and after the initiation of CBSP. The percentage in the food self-sufficiency category of less than three months and 3 to 5 months has decreased from 2.5% to 0% and 57.9% to 13.2% respectively (Figure 6). However, the percentage in the food self-sufficiency category from 6-9 months and 9-11 months increased by 12.4% and 29.8% respectively. It indicates that the initiation of CBSP has brought changes in the food self-sufficiency status within the community. The study also showed that 5% of the respondents have become self-sufficient for the entire year with the initiation of CBSP.

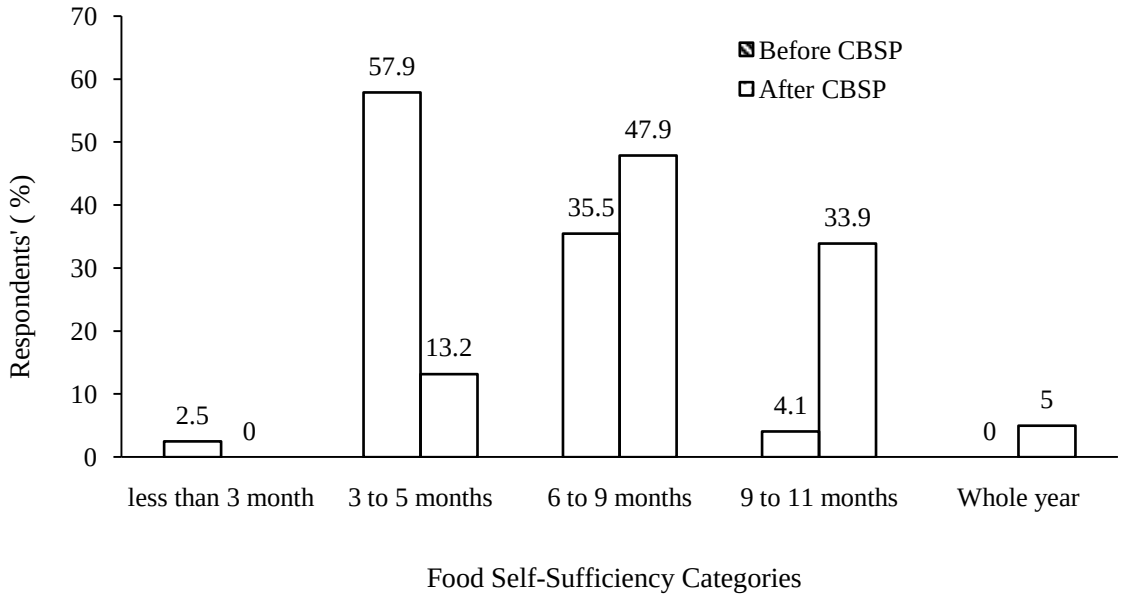

Figure 6. Household food self-sufficiency

Before, with low production, food insufficiency has been a major issue. The undesirable or poor quality of seed, depredation by wild animals and lack of farmers' capacity development had caused this issue. A similar study on assessing impacts of maize research through a livelihoods lens by Rovere et al (2009) found the initiation of CBSP in the community and growing improved varieties of maize have played an increasingly important role in improving livelihoods. The food self-sufficiency of participants in CBSP areas in Nepal improved from 11% in 2002 to 24% in 2006. The findings of Mathema and Gurung (2006) were similar to the cases in this study sites. The comparison in 2002 and 2006 showed that food self-sufficient households at each site increased. The number of farmers who were food self-sufficient for one year or more doubled due to adoption of maize technologies at CBSP sites. It clearly implies the direct positive impact of CBSP on food self-sufficiency.

3.8.3. Impact on price changes

The price of maize seed increased slightly compared to the past or at the initial establishment of CBSP. Since the National Seed Centre (NSC) is the major market for CBSP groups, the price of maize seeds is fixed by them. The average price of maize seed was Nu 18 per kg in 2011 which increased to Nu 20 in 2012. Every year the price was increased by Nu 1 and it was Nu 23 in 2016. The pricing fixed by NSC is higher than what they normally get (Nu 19-20 per kg). The pricing trend in CBSPs of Nepal for the five years was found to be increasing at all the sites. The average price of maize seed in 2003 was Nepali Rupee 14 per kg and NR 24 per Kg in 2007 (Upadhyaya et al 2014).

3.8.4. Impact on Marketing

All the respondents felt the changes in terms of marketing maize seed after the establishment of CBSP. Seed marketing is a recent trend in the community. After the establishment of CBSP, farmers experienced ease in marketing their seeds. The rate of seed marketing has

increased by 56.4% (21.3 ton in 2012 to 81.4 ton 2016) within the last five years (Figure 7). The increase in the sale of maize was mainly due to higher production of maize. Until 2014, only two older groups (Waichur and Changmey) were involved in the production of seeds. The seed marketing trend has increased within a short span of time. With the establishment of two new groups, the marketing of seed has increased. The decrease in rate of seed marketing trend in 2014 by 35.2% (18.4 ton in 2014 from 28.4 ton in 2013) was due to drought condition in the production sites which has hampered the quality of seed.

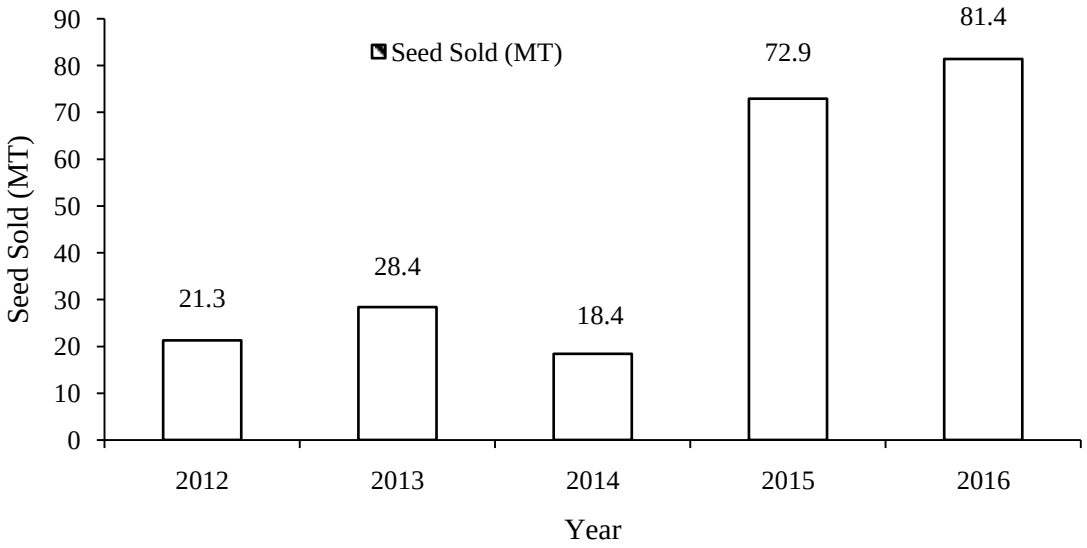

Figure 7. Seed marketing trend

Table 7 shows the major and frequently used market by CBSP members. The NSC based at Tashiyangtse is the major or main market for the CBSP groups since the groups are registered and linked with NSC. They also market their maize seed to other customers (10.9%) in the western part of the country as an animal feed and act as a seed source for their neighboring community who are not members of CBSP. Difficulty in the marketing of the produce in the past has encouraged the community in establishing CBSP. Today with the initiation of CBSP, the customers come at farmer's doorstep to buy the seed.

Table 7. Major markets

Major Market	Respondents' (%)
National Seed Center	88.1
Neighbors	1.0
Others	10.9
Total	100

Katwal et al (2007) reported that one main problem in marketing maize has been the absence of the critical mass of surplus. The surpluses are scattered and are quite small at the household level. It also reported that organizing the farmers into groups had facilitated in marketing and enhancing the bargaining power of the farmers. A study by Upadhyaya et al (2014) in the hills of Nepal reported an increase in the marketing trend of maize seed from

75% of the production sold in 2011 to 90% of the production being sold in 2013. A similar study on CBSP in the hills of Nepal by Hamal et al (2010) observed an increase in the marketing trend of maize seed sold by 33%; the seed sold has increased from 60% in 2003 to 80% in 2007.

4. Conclusion and Recommendations

The study showed that the initiation of CBSP had benefited the group members in various ways. CBSP concept has played an important role in increasing quality maize seed production and ensuring seed security, enhancing the socio-economic condition and food security. The annual maize production of the CBSP within the last six years (2011-2016) has increased by 45.4% (37.4 ton in 2011 to 139.2 ton in 2016). The increase in production is related to use of improved varieties and adoption of quality seed production. The study found that growing a single variety of maize in a community has resulted in quality seed production and has increased the seed security. It was noted that the technical support and free input supplies were received more often than before. Farmers are provided with training on quality seed production, seed selection and pest and disease management. The mobilization of the community into group has brought unity within the community as said by 13.3% of the respondents. The unity was mostly in terms of decision making. Some drawbacks of CBSP were on the loss of traditional varieties, increasing wage rate and labor shortage.

The field survey data clearly reflects the direct positive impacts of CBSP on food self-sufficiency. Most of the members have significantly improved their food self-sufficiency status. For example, the category of the farmers with food self-sufficiency of 6-9 months has increased by 34.9%. With the increasing productivity, the income trend has also increased by 54%. The mobilization of community into group has seen a change in marketing. Unlike before, today the buyer come to farmers' door-step to buy the seed and the price has also increased annually. The CBSP model should be mainstreamed into seed production groups and must be introduced in all the maize growing areas. However, CSBP may risk loss of traditional varieties. To address this, conservation of local germplasm should also be implemented side by side through both *in-situ* and *ex-situ* conservation approaches.

Acknowledgement

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Evaluation of Heat Tolerant Cole Crop Varieties

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ABSTRACT

Cole crops, which include Cabbage, Cauliflower and Broccoli among others, occupy major components of vegetables in Bhutan. They are also important source of income, earning Nu. 106 million in 2016 from Cabbage and Cauliflower alone. However, production of these crops is largely limited to winter season to at most early spring given that they require cool season for growth and development. But the predicted climate change is likely to affect these crops since they prefer cool climes, and also there is increasing demand for these crops round the year. Therefore, to address some of these issues, heat tolerant Cabbage and Cauliflower varieties were introduced and evaluated in research fields of Agriculture Research and Development Centre, Wengkhar, Monggar. Crops were evaluated at Khangma (2100m), Lingmethang (650m) and Wengkhar (1650m) conditions during peak summer season when existing varieties cannot be cultivated. Results show that both the heat tolerant cabbage variety, Asha and Bengal King, can be produced during peak summer season even under Lingmethang condition. Of the two, Asha has greater potential for export market given its ideal size for Indian markets. The study also showed that heat tolerant cauliflower varieties, White Express 50 and Pragati 40, can be produced during peak summer season. Given their smaller size, they are also suitable for export markets in India. Of the two, Pragati 40 is more tolerant to heat and hence more suitable for cultivation in low lying areas. In general, these varieties provide not only options but also opportunities to deal with the emerging issues and needs.

Keywords: *Heat tolerant; Cabbage; Cauliflower; Peak summer; Export market*

1. Introduction

Cole crops are cultivated species of *Brassica oleracea* that includes Broccoli, Cabbage and Cauliflower among others. These crops are called Cole Crops since they originated from wild cliff cabbage also known as Cole Worts (Agroinfo 2017). They are cool season crops and are usually grown during winter season. They prefer about 7 to 13^{o}C for optimal growth and development (AVRDC 1991). In Bhutan, among Cole crops, Cabbage and Cauliflower dominate in terms of production. For instance, in 2016, 6,685 ton of Cabbage and 2,082 ton of Cauliflower were produced, and sold worth Nu. 75 million and 31 million respectively (IMS 2016). Cabbage and Cauliflower varieties grown in the country today are conventional ones that prefer cool season that can be grown only during winter season, and they do not tolerate high temperature. Hence, as temperature rises due to anthropogenic climate change,

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these crops are likely to suffer negative consequences. In Bhutan, it has been observed that over the last two and half decades, temperature has risen by about 0.3 to 0.5^{o}C (Tse-ring 2010; Phuntsho & Dorji 2014). Given this, it could even lead to change in cropping systems. High temperature affects plant growth and development and may cause substantial reduction in economic yield of crops (Wahid 2007). Till date, there are no published studies that tried to address this critical issue. Further, there is demand for year-round production of these Cole crops both within the domestic markets and huge potential to export during hot summer season to India, which is not possible with the existing varieties.

In order to deal with rise in temperature and demand for year-round consumption, especially during summer, there is a need to look for varieties beyond the existing ones. Evaluation of heat tolerant varieties could be one of the adaptation strategies. Heat tolerant crop is defined as those crop species that have remarkable heat tolerance adaptability under high temperature with a promising yield (Wahid 2007). Hence, this study evaluated production of heat tolerant varieties of Cabbage and Cauliflower during peak summer.

2. Materials and Methods

The trial was conducted at Agriculture Research and Development Centre, Wengkhar (1650 m.a.s.l.) and Agriculture Research and Development Sub-Centres Khangma (2100 m.a.s.l.) and Lingmethang (650 m.a.s.l.). Heat tolerant varieties of Cabbage, Bengal King and Asha and Cauliflower varieties, White Express-50 and Pragati-40 seeds were procured from Pahuja Private Seeds Limited and East West Seeds in India. Seeds were sown in staggered manner so as to try to produce crops during peak summer season when normal varieties are not suitable for production. Trial was set up using Randomized Block Design and management practices were followed as recommended (Tshering et al 2009). From each plot, 10 heads/curds were randomly selected and recorded their weight, length and diameter, and compactness of head in the case of Cabbage. Date of seed sowing, transplant and harvest were also noted. The data were analyzed using SPSS 22. One way ANOVA was used to compare the mean yield and crop duration for all varieties. For multiple mean comparisons, Duncan multiple range test was used.

3. Results and Discussion

Existing cabbage varieties are normally produced from mid July to mid March in areas above 1800 m sea level, mid June to February in areas ranging from 1400 to 1800 m and November end to early February for below 1400 m. For Cauliflower, existing varieties are produced from end of September to February for 1800 m and above, December to January for 1400 to 1800 m and for below 1400 m (Horticutlure Sector 2015). The evaluation of new heat tolerant cabbage and cauliflower varieties provide promising result as they can be produced during the peak summer season even in low altitude areas like Lingmethang, which is located at around 650 m above mean sea level. However, one of the challenges of heat tolerant cole crops during peak summer season is enhanced pressure from pests and diseases.

3.1. Heat Tolerant Cabbage

Two types of heat tolerant cabbage varieties, Asha and Bengal King can be successfully produced during hot summer season under Lingmethang condition in just more than two months' period (Table 1). Bengal King had significantly larger head weight than Asha (P-value <0.001). However, Asha is ideal for export market (India) in terms of head size, compactness and colour since head with less than one kilogram is preferred in Indian markets.

Table 1. Cabbage evaluation at Lingmethang

Variety	Transplant to harvest (days)	Head weight (gm)	Harvest time
Asha	66	915±139[a]	June
Bengal King	68	1309±391[b]	June

3.2. Heat Tolerant Cauliflower

Heat tolerant Cauliflower varieties, White Express 50 and Pragati 40 can also be produced during summer season under Lingmethang condition though by nature these are small size compared to existing cauliflower varieties in Bhutan. These varieties can also be produced in much shorter duration than normal ones (Table 2). White Express 50 had significantly larger curd size than Pragati 40 (P value = 0.026). These are ideal size for export to Indian markets since they prefer curd with weight less than a kilogram (Phuntsho et al 2017)

Table 2. Cauliflower evaluation at Lingmethang

Variety	Transplant to harvest (days)	Curd weight (gms)	Harvest time
White Express 50	41	331±122[a]	June
Pragati 40	41	257±73[b]	June

3.3. Staggered Production Trial of Cauliflower

Among the Cole Crops, Cauliflower is most sensitive to temperature. Temperature either sides of its ideal range would lead to crop failure, and hence, cropping season is critical. To ascertain its ideal growing time, staggered production trial of the two varieties was conducted at Wengkhar condition during the summer season (Table 3 and 4). For White Express 50, of the three growing periods, June harvest produced significantly higher curd yield (*P* value <0.001) as shown in Table 3.

Table 3. Staggered evaluation of Cauliflower White Express 50

Harvest time	Transplant to harvest (days)	Curd weight (gms)
May	39	183±59[a]
June	63	433±126[b]
October	59	185±56[a]

Pragati 40 was tried in two growing periods. Among the two, June harvest gave significantly higher curd yield than October harvest (*P* value < 0.001). In fact, the result (Table 4) clearly showed that Pragati 40 is not suitable for production in October month and beyond, which indicates that it is more sensitive to cold (or rather more heat tolerant) than White Express 50.

Table 4. Staggered evaluation of Cauliflower Prgati 40

Harvest time	Transplant to harvest (days)	Curd weight (gms)
June	47	253±197[a]
October	59	58.0±25[b]

Heat tolerant varieties of Cauliflower were also tried under Khagma condition (2100 m) but bolted because of low temperature which is an indication of heat tolerant varieties. Further, as a control, normal Cauliflower variety, Wengkhar Metokopi I, was also tried for May, June and October production along with the two heat tolerant varieties. However, it failed to form curds during May and June and produced only during November. But the average weight of the curd was just 194 gm, which is significantly lower than its normal weight (600 gm) indicating that normal existing varieties cannot be produced during the summer season.

4. Conclusion

Cole crops are among the major vegetable crops that generate significant income for growers. These crops prefer cool season and hence are produced only during winter season to early spring. Expected rise in temperature due to climate change are likely to affect these crops, and also there is increasing demand for these crops during summer season. Hence, these heat tolerant varieties are expected to provide some solutions towards addressing the aforementioned issues.

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Graft Responses to three different techniques in Mango (*Mangifera indica* L.) under Bhutanese nursery conditions

Sonam Chophel[u] and Kinley Dorji[u]

ABSTRACT

Veneer grafting (Inarching) is a vegetative method of mass propagation of mango in Bhutan. However, this method of propagation has many setbacks in Bhutanese nursery conditions. The most important disadvantage of this method is high cost of production as grafting is done in field and seedlings are kept in open condition until proper graft union is formed. Providing graft aftercare in open field spread in large areas prove challenging in Bhutanese conditions. This study was aimed at identifying viable alternative methods of propagation to Veneer grafting. The experiment was conducted at Agriculture Research and Development Center, Bajo in 2015 in Horticulture Nursery Block. Three grafting techniques (Veneer, Splice and Wedge) were evaluated for different indicators of shoot, leaf and graft success. The results showed no significant difference ($p<0.05$) among the grafting techniques studied at 95% confidence interval. Initial rate of graft success before 20 DAG was higher for Wedge followed by Veneer or Inarching; however the gap narrowed after 60 DAG. Splice grafting showed higher rate of graft success (60%) and survival percentage (53) after 60 DAG than the veneer grafting (control). Our findings suggest that splice and wedge grafting can be safely followed for mass propagation of mango in Bhutanese nursery conditions. Further work on study of cost of production using different propagating techniques for mango would be useful for coming up with recommendation package.

Keywords: *Graft response, mango, grafting techniques, Bhutanese nursery*

1. Introduction

Mango is one of the important fruits in tropical belt of the world and more importantly in Asia. It is referred to as the King of Fruit in India due to its importance and historical significance. It is also a fruit of choice in Bhutan as it is successfully cultivated in wet tropical (below 600 meters above sea level) and to an extent in warm humid subtropical (600-1200 m.a.s.l.) agro-ecological zone in southern parts of the country. As per the Agriculture Statistics 2014, published by Department of Agriculture (2016), a total number of 57601 trees are in the field while the number of bearing trees is just about one-third (17458). Domestic production (586 ton) meets only about half the country's demand (1190 ton) and more than 582 ton are imported (Bhutan Trade Statistics, 2016). Therefore, enormous opportunity exists to upscale domestic production and to gradually replace import with domestic produce thereby achieving self-sufficiency.

Mango production in Bhutan is not without challenges. Increasing its production would require taking stock of production issues specific to Bhutanese scenarios and careful

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development of mitigation strategy. Mango is recommended to grow below 600 m.a.s.l., and often its production and yield is adversely affected by heavy rainfall especially when it coincides with flowering period. Also, fruit fly is one of the major problems to mango production (Ghalley et al 2014). More importantly, lack of quality seedlings is currently a major hurdle to mango production in the country. Regional Seed Center at Samtenling is the only government seed agency that produces mango seedlings although there are few private nurseries as well. These nurseries currently practice veneer grafting.

Grafting is the most common method of propagating fruit trees in order to obtain trueness-to-type. 'Inarching' or 'Approach grafting' is widely followed as a vegetative propagation technique both within the country and across the border in India (Nayak and Sen, 2000; Lynch and Roy 2015). The technique is proven to be most successful method of grafting (Kumaret al 2015). The graft take depends on several factors (Mulinge 2015) that are inherent to rootstock or scion wood (Pratap et al 2017), stage of scion wood and defoliation (Majeed et al 2014), time or season of grafting (Nayak and Sen 2000; Islam et al 2004; Ullah et al 2017), grafting technique (Kumar et al 2015), potting media (Kumar and Thakur 2016), binding material (Vasara et al 2017) and more importantly the grafting skills of nurserymen.

Inarching is claimed as the most reliable and economical method of mango propagation (Kumar et al 2015; Lynch and Roy 2015). It involves use of scion from the desired tree which is still attached to its own root systems and there is no need for waxing of scion wood as desiccation is less likely to occur resulting in higher rate of graft success (Donovan et al 2016). However, the technique is not without drawbacks. In Bhutanese condition where mother trees are in the field, the graft success depends largely on graft aftercare. In the open condition, managing individual grafted plants spread over an area involves huge costs thus questioning the viability and profitability. Further, the rootstock growing media in the polypot often gets dry at a faster rate and manual irrigation is the only method currently practiced. Thus, seedling mortality is high in Bhutanese nursery condition which in turn increases the unit cost.

Private nurseries import huge quantity of grafted mango seedlings from Indian border to cater to domestic demand. Not much has been done on generation of mango propagation technologies and the little information that is generated has not been extended to private firms resulting in direct import from Indian border. However, some observation trials on mango grafting have been done in Agriculture Research and Development Center, Samtenling. Therefore, this study was aimed at identifying appropriate grafting method for Mango using three different grafting techniques for generation and promotion of alternate propagation methods in the present context of Bhutanese fruit nursery conditions.

2. Material and Methods

The experiment was conducted at Agriculture Research and Development Center Bajo, Wangdiphodrang, which is located at an altitude of 1180 meters above sea level. One year old scion wood was collected from RDC mango germplasm block and grafted after 10 days of scion wood collection by using Wedge, Veneer and Splice Grafting techniques on 1st June, 2015 as higher graft success were reported during June to August (Islam et al 2004). Graft

aftercare and irrigation were provided twice weekly. The wedge and splice grafted seedlings were maintained in 70% green shading net while *Inarching* was done as usual in open field conditions.

Grafting was done following the procedures and guidelines published by Queensland Government and Department of Primary Industries, New South Wales Australia (Donovan et al 2016). The local rootstocks were raised in uniform sized poly pot (2 litre) containing same media mix and only rootstock of uniform size (1.2 cm diameter) at 20 to 30 cm height was used. Scion woods (c.v Deshari) of similar size (about 1 cm) were prepared by defoliating new season shoots (first flush) at least seven days before date of grafting The shoots for *Inarching* were kept intact with mother trees for about a week as defoliation has shown to improve early sprouting (Majeed et al 2014; Ullah et al 2017) while enough defoliated shoots were cut and wrapped with para-film to avoid desiccation for wedge and splice grafting. It was then stored at 12 degree centigrade for 3 days.

2.1. Wedge or cleft grafting

Wedge grafting is also known as cleft grafting. The scion wood was made two clean and sloping cuts (2.5-3 cm long) at its base forming a wedge which was then inserted into the clean-edged cut rootstock (at the height of 20-30 cm above the soil level) to match the cambium layer of scion and rootstock. Then it was tied firmly using grafting tape making air tight to prevent moisture loss and dislodging of scion.

2.2. Splice grafting

Splice grafting is also known as whip grafting. The scion wood was made a single-angled cut through both the rootstock and the scion wood of about equal length. It was then placed together in such a way to match the cambium layer at least at on one side if the size of the scion wood and rootstock were different.

2.3. Veneer grafting

This is also called as ‘Approach grafting’ or ‘Inarching’ and it is a usual method adopted in mango propagation. This technique involves large plant growing in a field as a mother plant and grafted without the scion detached from it. The rootstocks were placed appropriately near mother tree and tied up with the trunk of mother trees where convenient while some grafted seedlings were maintained on the temporary shelf until proper graft union was formed.

2.4. Data collection

The success of the graft in first few months can be determined by the indicators such as bud sprouts, shoot and leaf growth. The scion wood that sprouts from grafted plants put on growth and increases its shoot and leaf number over a period of time. The data was collected only after twenty days of grafting when prominent bud sprouted from the shoots and leaf primordial appeared on the grafted scion wood. A total of 20 plants were grafted for each grafting techniques and the data were collected on shoot growth (cm), number of shoots (SN), number of leaves (LN) and the percent graft take (%), for a duration of two months after twenty days of grafting at 10 days interval. The length and the size were measured using scale and Vernier caliper.

2.5. Data analysis

The indicators of the graft success assessed were the shoot growth referred here as shoot length (SL) and leaf growth as leaf length (LL) in cm. In addition, the number of shoots and the leaves were also evaluated. The graft success was calculated using success percentage for each observation as below:

$$Graft\ success\ (\%) = \frac{\text{Number of grafted plant survived}}{Total\ number\ of\ plants\ grafted}\ x\ 100$$

The variation among the grafting technique was analyzed using One-Way ANOVA using SPSSv16.0, IBM (2007) to assess the level of significance among the three different grafting techniques based on the variables related to graft take, growth of scion wood, leaf number, and growth trend. The variables of leaf and shoot length were compared and the results were presented using descriptive statistics as the corresponding trend in growth. The number of leaf (LN) and shoot number (SN) was also plotted as a performance of the graft for three different grafting techniques.

3. Results and Discussion

Veneer grafting is the only grafting technique that is currently deployed for mass multiplication of mango by nurseries in Bhutan. The grafting technique is preferred mainly for its high graft success and the associated advantages (Islam et al 2004; Kumar et al 2015). However, in Bhutanese nursery conditions, high unit cost per unit is mainly because of the high labor cost. Since *Inarching* involves grafting in the field, high labor is required for watering the plant in the field especially for rootstock raised in small poly pot. Labor requirement for hand watering increases the major chunk of production costs if the graft union is not formed before dry winter season. In addition, preparing stakes and shelf for the rootstock during graft union formation also involves additional cost.

The various graft success indicators for the variables were assessed up to two months after grafting. Statistically no significant difference (p>0.05) was observed among the grafting techniques deployed with respect to all variables; LN [$F(2,38)=0.29$, $p=0.74$), SN ($F(2,38)=1.13$,$p=0.33$), SG($F(2,38)=0.21$, $p=0.8$), LL ($F(2,38)=0.92$, $p=0.40$), SL ($F(2,38)=0.91$, $p=0.40$]. The highest percentage of survival was found in Splice grafting (53%) and the highest number of shoot was achieved in Wedge grafting (1.834). Similarly, the highest number of leaves at 60 days after grafting (DAG) was recorded for veneer grafting. The overall performance of the grafts is depicted in Figure 1.

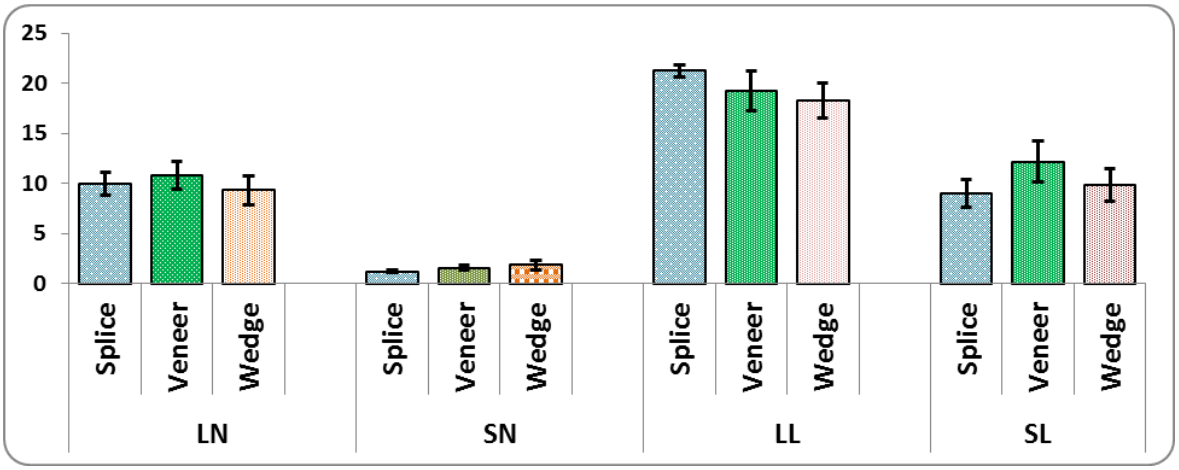


Figure 1.The mean of LN, SN, LL and SL for three grafting techniques 60 day after grafting

Note: (LL and SL refers to leaf length and shoot length, respectively in cm while LN and SN refers to Shoot Number and Leaf number with the corresponding error bar representing the variation in data (not the error in the measurement).

The highest overall shoot length (SL) and number of leaf (LN) at 60 DAG in case of Veneer grafting can be attributed mainly due to its parts still intact with the mother trees for continuous supply of nutrient to scion favoring easy graft union formation unlike the wedge or splice grafting. The lowest shoot length (SL), shoot number (SN), for splice grafting may be due to the time required for callus and graft union formation as scion woods are detached from its root system and there is no nutrient flow from rootstock to scion during the initial graft formation stage.

3.1.Trend of graft success, shoot and leaf growth

The study of trend in grafting success showed that Veneer grafting has lower graft success than splice in this study. It can be due to exposure of the grafted plants directly to outside environment (open condition) as *Inarching* is usually done in Bhutan. This open condition has shown to lower the rate of graft success in mango (Sivudu et al 2014). In real nursery conditions, graft aftercare especially not providing irrigation to the inarched plants suffers from high mortality. Although the differences in graft success were noticed during the initial stages of scion growth among the techniques deployed, their differences narrowed at the later stages (at 60 DAG). Therefore, considering the costs, other two grafting techniques (Splice and Wedge) can be a viable alternative to mango propagation.

We also assessed the growth rate for shoot and leaf at different stages of scion wood development phase. The sprouting began two weeks after the grafting date (1st June 2015). The graft success rate increased over a period of two months. Initially, splice grafting showed the lowest graft take (16%) while the highest (30%) was observed for wedge grafting. Later, splice grafting took a sharp climb in graft success rate for next one month (until 40th day) followed by wedge grafting. The graft success rate in veneer method remained low until 50 day after grafting and finally shot up to 50% at 60 DAG nearly catching up with the splice and wedge techniques. Considering the trend of graft success rate and the final percentage at

60 DAG, splice grafting technique proved superior against the widely adopted and recommended veneer technique.

The vigor of the scion growth also determines the success of graft at the later stages. In some crop species, early sprouting can be due to the stored nutrient of the scion wood without actually forming the graft union. We studied the ability of the scion to sprout before graft formation by Deshari Mango using stored nutrient in the scion wood. The growth rate of shoot and leaf length showed that veneer grafting attained highest shoot growth (6 cm) within 20 days of grafting followed by Wedge and Splice which again is due to continuous supply of nutrient from rootstock and scion mother tree. Although the growth rate increased for all the three techniques under evaluation, veneer grafting proved best (about 12 cm) at the end of 60 days followed by Wedge (10 cm) and Splice (8 cm) techniques. The study on leaf length for different techniques showed some variations at the beginning (20th day) however, over the period of two months, no significant difference in leaf growth was observed. Also, the grafted plants for all three techniques that did not form graft union showed no sprouting due to store scion nutrient as in other tree crops. However, the scion remained green for about a month after grafting as if it was still under graft union formation but eventually wrinkled and died. The trend in graft success, growth of shoot and leaf for different grafting techniques are shown in Figure 2.

Treatment	Graft success (%) Final	Date of observation	Graft take (%)	Shoot length (cm)	Leave length (cm)
Wedge	40	20/06/2015	30	2.5	7.0
		30/06/2015	30	3.7	13.3
		10/07/2015	40	6.0	14.9
		20/07/2015	40	6.2	16.0
		30/07/2015	40	9.9	18.3
Veneer	40	20/06/2015	20	5.0	10.0
		30/06/2015	30	5.3	11.8
		10/07/2015	30	5.8	13.7
		20/07/2015	30	8.0	17.3
		30/07/2015	40	11.2	17.9
Splice	60	20/06/2015	10	2.4	8.4
		30/06/2015	40	2.4	11.3
		10/07/2015	50	5.0	14.8
		20/07/2015	50	5.1	17.1
		30/07/2015	60	11.1	18.9

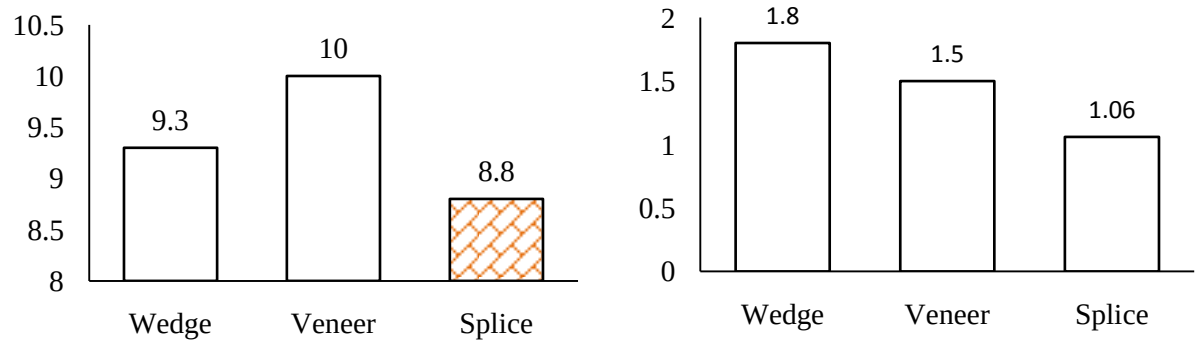
Figure 2.The trend in Graft success (A), shoot length (B) and Leaf length (C) for three grafting techniques over a period of two months after grafting

3.2. Shoot Number and Leaf Number

The number of leaves per graft was high for veneer grafting (10) followed by Wedge (9.3) and Splice (8.8). However, number of shoots per graft was highest for Wedge (1.8) followed by Veneer (1.5) and finally the Splice (1.06). As reported by Omer et al (2016), there was no

significant effect of grafting techniques on number of leaf but our result differed slightly in terms of number of shoots as variation was observed among the three techniques.

The difference in number of shoot and leaf as affected by three grafting techniques under evaluation is shown in Figure 3.



A. Number of leaf per graft B. Number of shoot per graft

Figure 3. Number of leaves and the shoots per graft for different grafting techniques

4. Conclusion

Our assessment for different grafting techniques showed statistically insignificant differences among the grafting techniques (Veneer, Splice and Wedge) indicating that other grafting techniques (Splice and Wedge) can be viable alternative to currently adopted veneer grafting. The percentage of graft success and the trend of graft success also showed no significant difference. Similarly, no variations were found for number of leaf and shoot per graft for different techniques. All the grafts that were successful showed sprouting from scion wood within two weeks after grafting. Considering the parameters (graft success, variables of leaf and shoots) in this study, Splice or Wedge grafting can serve as alternative methods for propagating mango so that the unit cost for mango seedlings can be reduced. However, further economic studies on the cost of production of mango seedlings may provide further insights about the feasibility of the wedge and splice method.

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Characterization of Six Varieties of Banana (*Musa paradisiaca* L.) Grown in Sarpang Dzongkhag

Chinta Mani Dhimal[v] Tulsi Gurung[w] Ngawang[v]

ABSTRACT

Twelve local banana (Musa paradisaica L.) varieties are popularly cultivated in Sarpang Dzongkhag but lack proper information on their characters. Therefore, evaluation on their morphological and compositional characters of six commonly grown varieties was conducted in Hilley and Shompangkhag geog under Sarpang. The purpose of the study was to identify morphological and compositional characters that have relationship and differences among six banana varieties. Using quantitative characters, through cluster analysis, they were grouped into four. Significant difference was observed in pseudo-stem height, pseudo-stem diameter, leaf blade length, leaf blade width, peduncle width, number of fingers per hand, finger length and finger weight. No significant difference was observed in bunch weight among six varieties. Peduncle length was similar among the varieties. Bunch weight was correlated with peduncle width and number of fingers per hand. Qualitative characters related to leaf, growth habit, bunch, rachis, male bud, bracts, male flower and fingers were observed. Dhusrey had generally different characters compared to other varieties. Through cluster analysis on compositional characters, they were grouped into two. Significant difference was observed in pulp pH and dry matter content while no difference was found in TSS, ash and protein content among six varieties. Compositionally Jhaji had comparatively different characters while others were similar.

Keywords: *Morphological; Characterization; Compositional; Quantitative; Qualitative*

1. Introduction

Banana belongs to genus *Musa* under the family Musaceae which are grouped into five sections such as; Emusa, Australimusa, Calimusa, Rhodochlamys, and Incertaesedis based on the basic chromosome numbers, arrangement and orientation of flowers in inflorescence (UNCST 2007). Jesus et al (2009), Nakasone & Paull (2004) & Ploetz et al (2007) mentioned that most of the cultivated bananas (*Musa paradisiacal* L.) belong to Emusa section and are the inter specific cross between *Musa acuminate* Colla (A genome) and *Musa balbisiana* Colla (B genome). Simmonds & Shepherd (1955) used taxonomic scoring method to classify the edible bananas and to confirm on their evolution. Stover & Simmonds (1987) mentioned that *Musa* genus has 30 - 40 species. Simmonds & Shepherd (1955) stated that the cultivated banana (*Musa paradisiacal* L.) which originated primarily in Indo-Malaysia is a natural hybrid and differs from wild ones. It is cultivated in more than 130 countries throughout the tropical and subtropical regions (Gibert et al 2009) with estimated world production of about 106.54 million tons from an area of 5.16 million hectares in 2011 (FAO 2013).

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Honfo et al 2011, found that the children and mother in Nigeria and Cameroon eat bananas and plantains as boiled, fried, porridge, roasted paste and ripe. In Uganda the daily consumption of banana exceeds 1.6 kilograms per person, ranking highest in the world which provides more than 25% of carbohydrate requirement (Asten & Staver 2012). It contains 70% water, 27% carbohydrates, 0.5% crude fibre, 0.3% fat and 1.2% protein (Bal 1997). The physicochemical properties of banana are being influenced by environmental factors especially altitude. However, dry matter content is more stable than other chemical properties such as bunch and pulp weight (Gibert et al 2009). In cool climate, the fruits are smaller and fewer suckers are developed. Kumar et al (2005) mentioned that the quality of fruit and yield of banana varieties are affected by agro climatic condition and altitude.

Oliveira et al (2007) found considerable amount of ashes (composed of potassium, calcium and silicium salts) in all the morphological parts. Selvamani et al (2009) mentioned that carbohydrate is the principal component of green bananas which changes during ripening process. Soltani et al (2010) found that pH decreased from ripening stage one till three, then increased until stage seven. However stage six is an optimum stage for fruit consumption as it is the full ripening stage and delicious to eat. Forster et al (2003) from their study on distribution of nutrient inside the pulp found that ash and protein concentration was higher in the central part of pulp than on external part. In Spain, paediatricians recommend to avoid central part of pulp while feeding to children due to its difficulty in digestion. The nutrients in food required by body for maintenance, growth and other functions are provided from dry matter portion of food. Therefore, food formulations are prepared based on the dry matter content of food materials since nutrient requirement is on dry nutrient basis (Mertensa et al (n.d.).

In Bhutan they are grown mostly on small and semi- commercial scale. They are commonly cultivated in almost all the Dzongkhags except Bumthang, Gasa, Thimphu, and Paro. At national level, the annual production was 1,434 ton in 2004 (DoA 2004) which increased to 2,208 ton in 2010 (DoA 2010). However the leading Dzongkhags in terms of production are Sarpang and Samtse with 511 ton and 439 ton respectively (DoA 2010). From the same source it was found that the banana production in Hilley and Shompangkha geogs (study area) was 3 ton each in 2004 which increased to 15.12 ton and 214.19 ton respectively in 2010.

Many local varieties of banana are grown such as; *Chinichampa, Dhusrey, Jhaji,* (Council of RNR Research 2005) *Gheukola, Tinkesrey* and *Jhappari*without much knowledge on morphological and compositional characters. The only distinguishing methods at present are based on the farmers' information and physical appearance of the fruits. It is crucial to develop information on morphological characteristics on the available varieties and their yield potential which is important in income generation as well as nutritional benefits to farmers (Khampa 2012). Minimum studies have been conducted on their characters in Bhutan and limited information available on varietal characteristics. Only two varieties which were released as of now by National Seed Centre in 2002 are *Jhaji* and *Chinichampa* (DoA 2010). The aim of the present study was to identify and evaluate the relationship and differences on

morphological and compositional characters among six different varieties of cultivated desert banana *(Musa paradisaica* L).

2. Materials and Methods

2.1. Study area

The evaluation was done in Hilley and Shompangkha geogs under Sarpang Dzongkhag which are the leading producer of banana (DoA 2010). Similar to the characterization study conducted by Gibert et al (2009) on the consumption pattern and preferred varieties. Six varieties that are commonly cultivated were selected for characterization. These are *Jhaji, Ghewkola, Chinichampa, Jhappari, Tinkesrey* and *Dhusrey*. As per UPOV (2010) and IPGRI (1996), characterization should be done by raising germplasm block and preferably during 2nd and 3rd cropping cycle. However, due to the non-existence of germplasm block in Bhutan, evaluation was done by randomly selecting the plants in the farmers' field (*in situ)* in two geogs with matured fruits.

2.2. Sampling procedure

For attaining precision level of 0.10%, minimum number of one tree with six to ten fruits per tree is sufficient for most characters in avocado (Ledesma 1987). Mattos et al (2010) conducted agronomical and molecular characterization of banana using five plants per variety in a germplasm. In this study, four plants per variety were drawn for observation.

2.3. Qualitative characterization

Twenty qualitative characters were used for six plant parts such as three characteristics for pseudostem, one for leaf, five for inflorescence, two for bract, two for male flower and seven for fruits. For leaf habit, observation was made from a distance of 20 to 25 meters from the tree from all sides while dwarfism was observed through close view on petiole base. Sap colour was observed by puncturing the pseudostem and allowing sap to ooze out. Petiole margin was observed at the point where the petiole and pseudostem meet.

2.4. Quantitative characterization

Eleven quantitative characters were used for four plant parts such two characteristics for pseudostem, three for leaf, two for peduncle and four for fruit. Pseudostem height was recorded from the base of pseudostem to the point of peduncle emergence using measuring tape. Pseudostem diameter was measured at 0.3 meters above the ground by making cross sectional cut as per UPOV, 2010 guidelines. For leaf blade length, third leaf from the bunch emergence was taken and measured from extreme end point of midrib till the blade ends on petiole. Width was measured at the maximum point. Petiole length was measured on the same leaf from lamina till pseudostem. Length of peduncle was measured on the inner part from leaf crown to the first hand of fruit using measuring tape. The width of peduncle was measured using vernier caliper (15 centimeter long, Bristol) at the midpoint of peduncle.

Middle hands from each bunch were taken to find the number of fingers per hand as per the method used by Gibert et al (2009). The length of fruit was measured using vernier caliper on the internal arc of the fruit excluding pedicel of matured fruit. The bunch weight per plant was measured at fruit maturity immediately after harvest using electronic digital weighing

balance (30 kg capacity) by removing peduncle above the first hand and rachis below the last hand. As studied by Muchui et al (2010), fingers were weighed by selecting four fruits from middle hand at matured stage along with the pedicel immediately after harvest using electronic digital weighing balance (model: AND EK - 610i) with maximum weight limit of 600 gram.

2.5. Compositional characterization

Gibert et al (2009), evaluated for characters such as; dry matter content, pH, ash content, total nitrogen content, soluble sugars, total sugars, starch content and minerals (Potassium, calcium, magnesium and sodium) from the fruit pulp. In this study, due to lack of lab test facilities only five characters (pH, Total Soluble Sugar, dry matter content, ash content, and protein content) were analyzed in College of Natural Resources (CNR) laboratory.

From each bunch, three ripened fingers from middle hand were selected for lab analysis Fruit pulp pH was determined using pH meter. TSS was determined using digital refractometer (GMK - 701AC, G - WON) and cross checked with hand held refractometer. This was performed as per the procedure followed by Muchui et al 2010, who used Atago hand held refractometer. Proximate analysis was performed as per the study conducted by Ramli et al (2010) for determining dry matter and ash content. Ash content was determined as per the chemical composition analysis byOliveira et al (2007). Protein content was determined by Kjeldahl method as mentioned by McDonald (1977).

2.6. Data Analysis

The data was entered into Microsoft Excel 2007 spread sheet and the statistical analysis was done using Statistical Package for Social Science (SPSS) 16.0 version. Both for quantitative and compositional characters descriptive statistics were computed. Non parametric test was done to analyze the differences in characters using Kruskal-Wallis and chi square value at 0.05 significant level. Cluster analysis was done by Ward method of dendogram and assessed at squared Euclidean distance of five. Relationship on the characters among varieties was done by Bivariate Spearman correlation. For qualitative characters frequency table was constructed.

3. Results and Discussions

3.1. Quantitative characters

Using quantitative characters, cluster analysis was done by Ward method of dendogram and assessed at squared Euclidean distance of five (Figure 1). *Jhaji* and *Dhusrey* were in separate groups while *Chinichampa* and *Jhappari* were similar in their characteristics and the *Gewkola* and *Tinkesrey* were similar. The result indicated that there were some differences and similarities in quantitative morphological characters among six varieties. Mattos et al (2010) found that there were significant differences in agronomical and morphological characters among 26 banana varieties studied. Therefore, their finding was used for banana breeding and developing into triploid and tetraploid hybrids along with better agronomic traits.

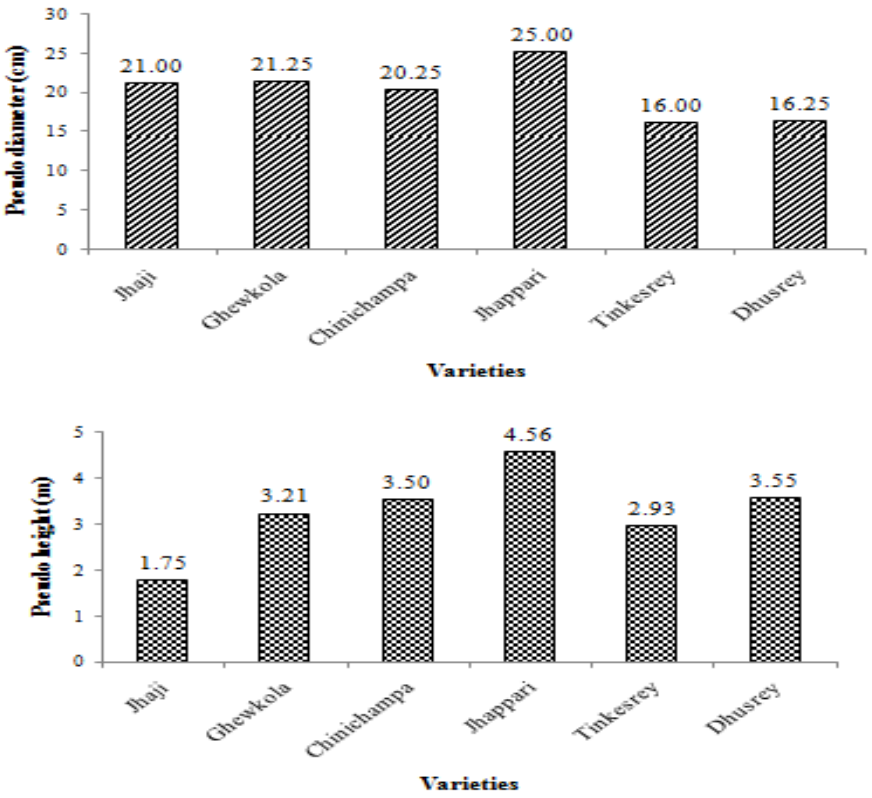

Figure 5. Mean of pseudostem diameter (above) and height (below)

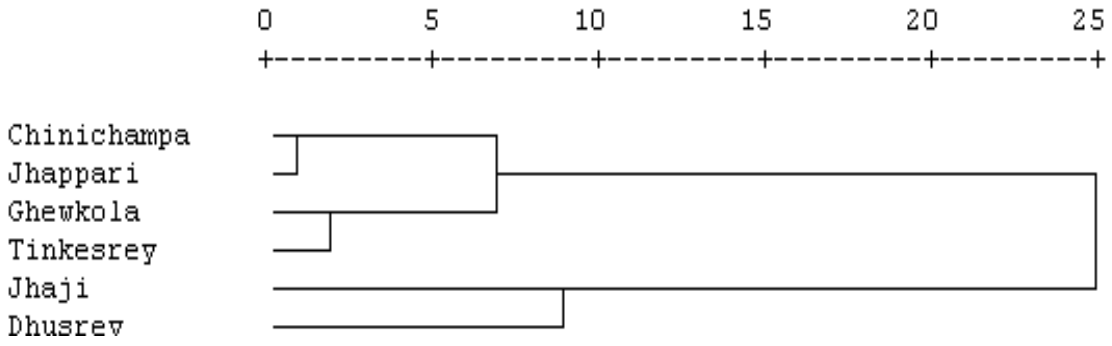

Figure 6. Dendogram based on general quantitative characters

3.1.1. Pseudo-stem characters

Kruskal-Wallis test showed that there was significant difference on the height of pseudostem among six varieties, $H(5) = 14.256$, $p = .05$. The maximum mean pseudostem height was in *Jhappari* and minimum in *Jhaji* (Figure 2). Pseudostem diameter was significantly different among varieties $H(5) = 12.10$, $p = .05$. The maximum pseudostem diameter was observed in *Jhappari* and minimum in *Tinkesrey* (Figure 2). The difference in pseudostem height and

diameter may be due to the differences in growing micro environment, climatic conditions, management and varietal characteristics. Ara et al (2011) found significant variation in pseudostem height and diameter among three varieties. The authors also concluded that the differences was due to edaphic, climatic and management factors.

3.1.2. Leaf characters

Kruskal-Wallis test showed that there was highly significant difference on the leaf blade length of banana among six varieties, $H(5) = 15.47$, $p = .01$while Leaf blade width was significantly different among the varieties $H(5) = 13.68$, $p = .05$.

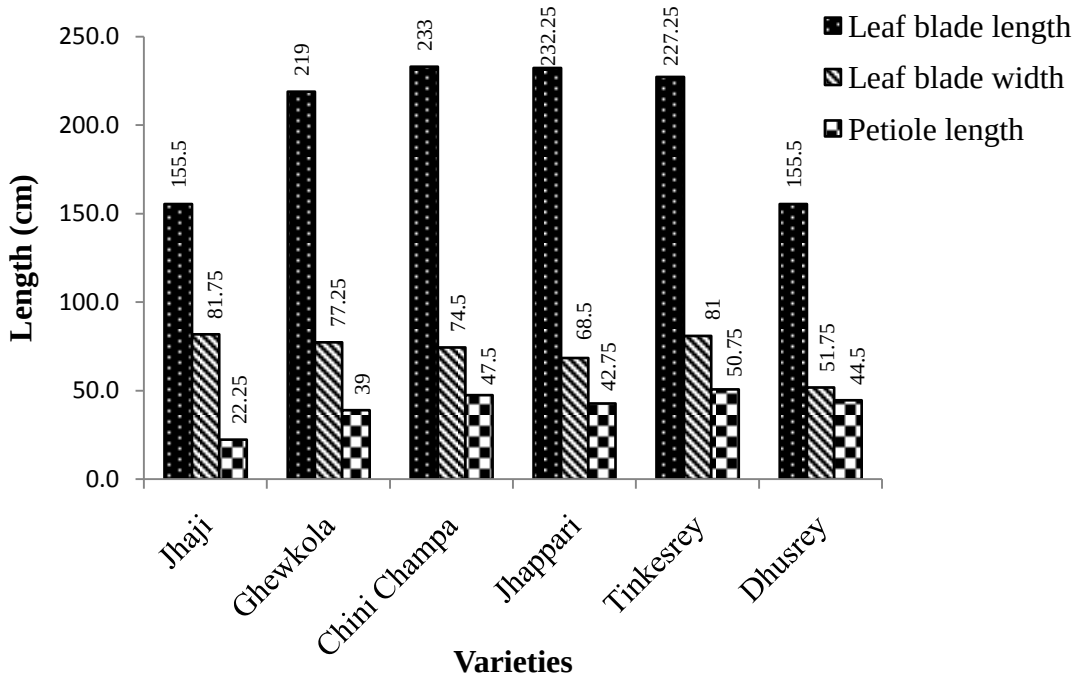

Figure 3**.** Mean of leaf blade length, width and petiole length

There was significant difference on petiole length among six varieties, $H(5) = 14.90$, $p = .05$. Ara et al (2011) from their study concluded that the differences in length and width of leaf and petiole length were due to the diversity of climatic conditions, season and varieties. Therefore, the significant differences found from this study revealed the same conclusion. The maximum mean leaf blade length was observed in *Chinichampa* with 233 cm while minimum was 155.5 cm in *Jhaji* and *Dhusrey*. The maximum mean leaf blade width was observed in *Jhaji* (81.75 cm) and minimum in *Dhusre*y (51.75 cm). With respect to petiole length the longest petiole was 50.75 cm in *Tinkesrey* and minimum in *Jhaji* with 22.25 cm (Figure 3).

3.1.3. Peduncle characters

From Kruskal-Wallis test no significant difference was found among six banana varieties on peduncle length while highly significant difference was observed on peduncle width among the varieties, $H(5) = 15.50$, $p = .01$. The maximum mean peduncle length was recorded in *Dhusrey* with 52.50 cm (n=4) and minimum with 27 cm in *Jhaji* variety (Figure 4). With

regard to peduncle width the maximum mean was recorded as 6.22 cm (n=4) in *Jhaji* and *Jhappari* and minimum with 4.22 cm in *Dhusrey*. The result revealed that the length of peduncle can be of any length to hold the bunch on the tree. However the width is important according to the weight the bunch in order to hold and support on the tree. Therefore, there was no difference in peduncle length but had differences in width.

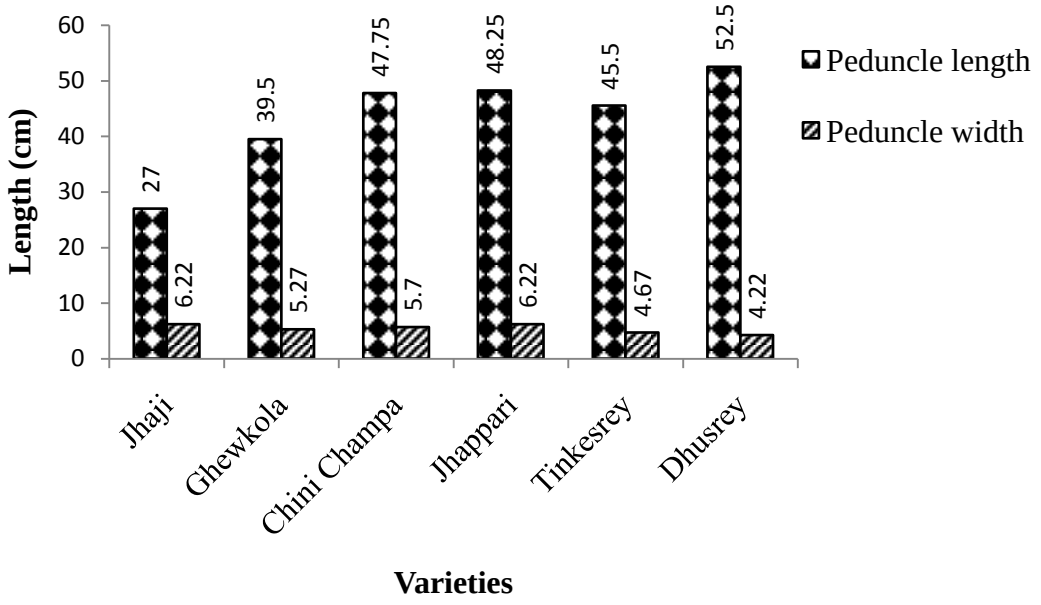

Figure 4. Mean of peduncle length and width

3.1.4. Fruit characters

Kruskal-Wallis test showed that there was highly significant difference on the number of fingers per hand $H(5) = 17.95$, $p = 0.01$, finger length $H(5) = 17.285$, $p = 0.01$ and finger weight $H(5) = 17.550$, $p = .01$ among six banana varieties. Arra et al (2011) concluded that there were differences in number of fingers per bunch, finger weight, length of fingers and bunch due to varieties and season. From the field study it was observed that number of fingers, weight of fingers and length were different based on the varieties. Kruskal- Wallis test showed no significant difference on bunch weight among varieties. In a study conducted by Bathan and Lantican (2010), it was found that yield of banana depends upon input utilization; types of cultivar planted and soil type. This study was also carried out in same area with similar soil type and other factors. Therefore, there was no difference in bunch weight among the six varieties which contributes to yield. The maximum number of fingers per hand was recorded in *Jhaji* (17.25) and minimum in *Dhusrey* (10) (Table 1). Fingers were longest in *Dhusrey* and shortest in *Ghewkola*. Maximum bunch weight was recorded in *Jhaji* and minimum in *Dhusrey* while finger weight was maximum in *Dhusrey* and minimum in *Chinichampa* (Table 1).

Table 1.Mean values of fruit characters

Varieties	Number of fingers/hand	Finger length [cm]	Bunch weight (kg)	Finger weight (gm)
Jhaji	17.25	11.22	15.48	88.75
Ghewkola	13.75	9.55	11	88.25
Chini Champa	16.25	7.725	13.13	45
Jhappari	14	10.22	12.05	65.75
Tinkesrey	13	12.07	9.92	120.5
Dhusrey	10	14.35	8.9	157.5

3.1.5. Correlation among quantitative characters

A bivariate spearman correlation coefficient was conducted among quantitative characters (Table 2). The reason for conducting correlation coefficient was to explore on which characters are well associated and useful for varietal selection (Putta et al (2013). Bunch weight was associated with pseudostem diameter (r = 0.49, p = 0.05) indicating that larger pseudostem diameter had more bunch weight. Bunch weight was highly associated with peduncle width (r = .64, p= 0.01) and number of fingers per hand (r = 0.73, p= 0.01). The results indicated that heavier bunch with wider peduncle had more number of fingers. O'Farrell (1987) concluded that the weight of bunch was due to the increase in number of fingers per bunch.

Pseudostem height was associated with length of leaf blade (r = 0.44, p= 0.05) and petiole length (r = 0.49, p= 0.05) whereas pseudostem height was highly associated with peduncle length (r =0.62, P= 0.01). The result revealed that higher the height, longer the leaf blade, petiole and peduncle. A study conducted by O'Farrell (1987) confirmed that **t**here was an increase in bunch weight (16.5 kg) with an increase in height of the pseudostem. Pseudostem diameter had highly significant correlation with peduncle width (r= .72, p= 0.01) and significant correlation with number of fingers per hand (r = 0.48, p= 0.05). This indicates that any change in pseudostem diameter will lead to change in width of peduncle. Leaf blade length was associated with leaf blade width (r=0.42, p= 0.05) and petiole length (r = 0.43, p= 0.05). The result revealed that leaf blade length was proportionate to leaf width and petiole. There was significant correlation between leaf blade width and peduncle width (r = 0.45, p= 0.05) and number of fingers per hand (r = 0.48, p=0.05). Petiole length was highly associated with peduncle length (r = .70, p= .01) indicating that longer the petiole longer the peduncle.

Negatively high association was observed between peduncle width and finger weight (r = -0.52, p=0.01) and positive association with number of fingers per hand (r = .81, p = .01). The result indicated that increase in peduncle width may not necessarily increase finger weight while increase number of fingers per hand. Fruit length was highly correlated with finger weight (r =0.68, p= 0.01) indicating that increase in fruit length increases finger weight. Negative correlation was observed between finger weight and number of fingers per hand (r = -0.63, p= 0.01). The results indicated that increase in finger weight decrease number of fingers per hand.

Table 2. Bivariate Spearman correlation among quantitative characters

Characters	BW	PH	PD	LBL	LBW	PTL	PUL	PUW	FL	FW	NFH
Bunch weight (BW)	1	-0.07	0.49*	-0.01	0.16	-0.15	-0.14	0.64**	-0.32	-0.37	0.73**
Pseudo height (PH)	24	1	0.35	0.44*	-0.32	0.49*	0.62**	0.05	0.00	-0.09	-0.28
Pseudo diameter (PD)	24	24	1	0.29	0.20	-0.18	0.06	0.72**	-0.37	-0.26	0.48*
Leaf blade length LBL)	24	24	24	1	0.42*	0.43*	0.34	0.3	-0.33	-0.4	0.1
Leafblade width(LBW)	24	24	24	24	1	-0.05	-0.35	0.45*	-0.05	-0.26	0.48*
Petiole length (PTL)	24	24	24	24	24	1	0.70**	-0.27	0.13	0.03	-0.27
Peduncle length (PUL)	24	24	24	24	24	24	1	-0.15	0.16	0.13	-0.26
Peduncle width (PUW)	24	24	24	24	24	24	24	1	-0.29	-0.52**	0.81**
Finger length (FL)	24	24	24	24	24	24	24	24	1	0.68**	-0.39
Finger weight (FW)	24	24	24	24	24	24	24	24	24	1	-0.63**
No. Finger/hand (NFH)	24	24	24	24	24	24	24	24	24	24	1

3.2. Compositional characters

Using compositional characters (pH, total soluble solids, dry matter content, ash content and protein content) cluster analysis was done by Ward method of dendogram and assessed at squared Euclidean distance of five (Figure 5). *Jhaji* was alone while other varieties were in one group.

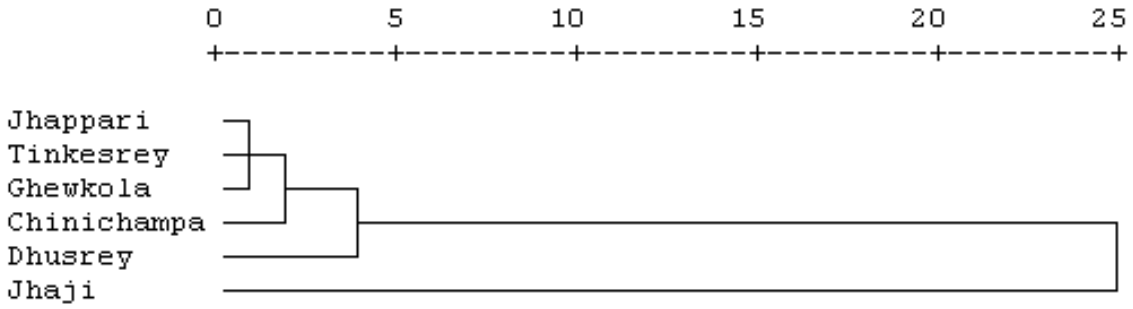

Figure 5. Dendogram based on general compositional characters

3.2.1. Pulp pH

Kruskal-Wallis test showed that there was highly significant difference in pulp pH among six banana varieties, $H(5) = 15.97$, $p = 0.01$. The maximum mean pH was recorded in *Jhaji* (5.04) and minimum in *Dhusrey* (4.08) (Figure 6). Banana pulp pH was recorded 5.02 at ripening stage one which decreased to 4.93 at seventh stage (Soltani et al 2010). In this study, pH was analyzed at full ripening stage and the findings were as per their study. Fruits with higher pH value have lower titratable acidity representing better fruit quality which is preferred by consumer and vice versa. Therefore *Jhaji* variety with high pH value indicates low titratable acid content and preference of consumers.

3.2.2. Dry matter content

Kruskal-Wallis test showed that there was significant difference in pulp dry matter content among six banana varieties, $H(5) = 11.43$, $p = 0.05$. Maximum dry matter content was in *Dhusrey* (29.60%) and minimum in *Jhaji* (19.80%) (Figure 6). Gibert et al (2009) found the

differences in dry matter content among 23 varieties which ranged from 19.6 to 30.9 %. From their study they concluded that the dry matter content was due to the genotype and their interaction depending upon varieties. Therefore the result found from this study revealed that the differences in dry matter content were due to the varietal differences. Several studies have shown different dry matter content in different varieties and climatic conditions. Gibert et al (2009) from their study concluded that the difference in dry matter content in different banana varieties pulp was due to varieties and environmental effects especially related to altitude. Therefore, the differences observed from this study may be due to varietal characteristics. Mertensa et al (n.d.) stated that formulation of rations is prepared on dry matter basis as animal require specified amount of dry nutrient. The authors also mentioned that most of the food ingredients requirements are met from dry matter portion of food materials. Therefore higher dry matter provides more nutrients to the body. So, *Dhusrey* variety is preferred for more nutrient supplement due to its high dry matter content.

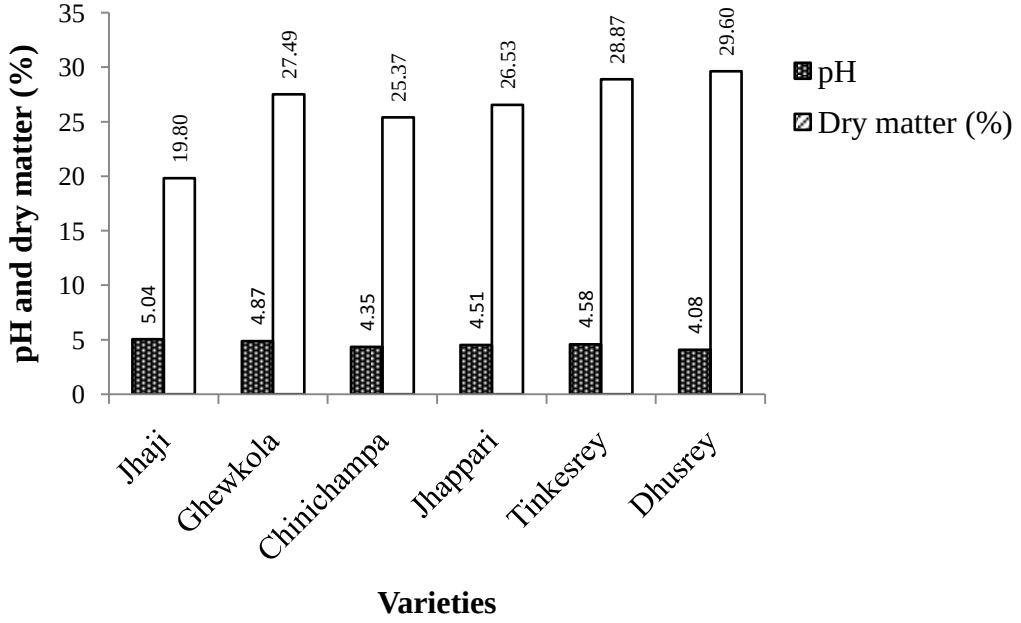

Figure 6. Mean of pH and dry matter of six varieties

3.2.3. TSS, ash and protein content

Kruskal-Wallis test showed that there was no significant difference in TSS, ash content and protein content among six banana varieties. Soltani et al (2010) from their study concluded that TSS of banana pulp increased till seventh ripening stage (21.9%) and declined further. The authors also mentioned that TSS indicates the amount of available sugar content in the pulp which indicates the sweetness of fruit. Mattos et al (2010) found mean TSS of 19.48 % with minimum of 14.60 % in Towoolle variety and maximum of 25.70 % in Teparod variety. In this study the maximum TSS was in Dhusrey (22.47%) and minimum in Jhaji (15.33%) (Figure 7). In this study, mean TSS is 19.24% which is lesser than their findings indicating that TSS was tested before sixth ripening stage (eating stage).At sixth stage (full ripe stage) the peel colour is all yellow, fresh and delicious to eat called as eating stage. At seventh ripening stage, the peel colour declines and have brown spots on the surface, sugar content

will be highest, and flesh becomes soft which is at declining phase. According to Fedha et al (2010) pumpkin fruit contained higher ash content than in seed indicating that mineral intake in the diet can be enhanced by eating pumpkin fruit. Oliveira et al (2007) found that considerable amount of ashes (composed of potassium, calcium and silicium salts) was found in all the morphological parts.

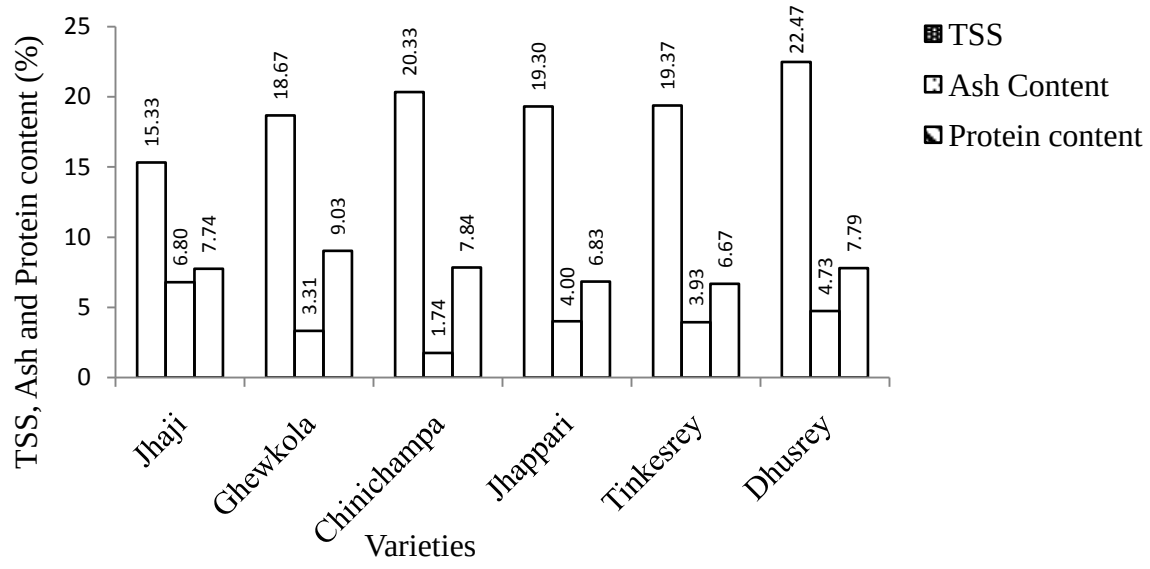

Figure 7. Mean of TSS, ash and protein content of six varieties

Gibert et al (2009) found ash content in desert banana as 2.3 to 4.3 % which varied between varieties. In contrary to it, this study found higher ash content indicating the consumption of fruit contribute better diet to human body. The maximum ash content was in *Jhaji* (6.80%) and minimum in *Chinichampa* (1.74%) (Figure 7).Therefore *Jhaji* variety is preferred variety for ash intake. Protein is good for children, lactating mothers and old people who need more proteins for growth, maintenance and repair of worn out tissues (Fedha et al 2010). Mahapatra et al (2010), found that the protein content was recorded as 2.2% which was lower than this study. This could be due to ripening stage, variety and climatic conditions. The authors also mentioned that protein content increases over ripening process depending upon genotype, variety, growing altitude and climate. Highest protein was found in *Ghewkola* (9.03%) and minimum in *Tinkesrey* (6.67%) (Figure 7). Therefore, protein intake can be enhanced by eating *Ghewkola* than other varieties.

3.3. Qualitative characterization

Twenty important qualitative morphological characters are reported through frequency distribution table (Table 3). Based on leaf habit, bananas were being grouped into three; *Jhaji* had erect, *Chinichampa* and *Jhappari* intermediate and *Ghewkola* and *Dhusrey* had drooping leaves. Based on dwarfism, only *Jhaji* was dwarf type with leaves strongly overlapping while the rest of the varieties were normal. With respect to sap colour, they were grouped into two; *Jhaji* and *Ghewkola* had watery sap while rest had milky. In terms of petiole margin, *Jhaji* and *Ghewkola* were winged while others were without wing along the petiole (Figure 8).

Considering bunch position they were grouped into three such as; group one included *Ghewkola* with bunch position at 45^{o} angle, group two included *Jhaji* and *Dhusrey* hanging vertically and group three included the *Chinichampa, Jhappari* and *Tinkesrey* positioned at an angle (Figure 9).

Figure 8. Petiole margin of six varieties (A = Jhaji, B = Ghewola, C= Chinichampa, D = Jhappari, E = Tinkesrey and F = Dhusrey)

Figure 9. Petiole margin of six varieties (A = Jhaji, B= Ghewola, C= Chinichampa, D = Jhappari, E = Tinkesrey and F = Dhusrey)

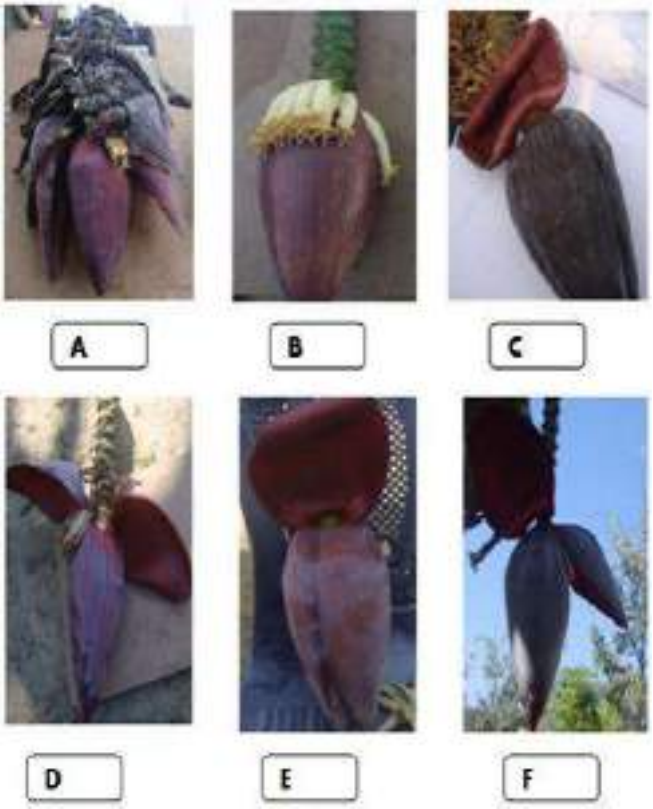

Figure 10. Male flower behaviour (A = Jhaji, B = Ghewkola, C = Chinichampa, D = Jhappari, E = Tinkesrey and F = Dhusrey)

Figure 11. Shape of style of six varieties

Two varieties (*Ghewkola and Chinichampa*) were in one group while others were in other based on rachis position. However, looking at rachis appearance those six varieties were grouped into three. Observing male bud, they were divided into two groups; Jhaji and *Ghewkola* had colour stripes on bracts while others did not have. Based on the bract behavior before falling, they were divided into two groups such as revolute (*Ghewkola, Chinichampa, Tinkesrey* and *Dhusrey*) and non revolute (*Jhaji* and *Jhappari*). Bananas were clearly

classified into three groups based on male flower behavior (falling before the bract, falling after the bract and neutral/male flowers persistent) (Table 3) (Figure 9). Observing the shape of style, they were grouped into two such as; curved at the base (*Chinichampa*) and straight (Figure 11).

Other characters such as fruit apex, remains of flower relics and peel crack were also studied as reflected in Table 3. General appearance of fingers of six varieties is in figure 12 and hands in Figure 13. These characters are useful for banana promotion through variety selection. Dwarf variety (*Jhaji*) can be selected in areas with strong wind to prevent lodging. *Jhappari* is recommended for those who prefer varieties with larger pseudostem for dual purpose (cattle feed and fruit). For longer transportation and storage, *Ghewkola* is preferred since its fingers remain attached with the hand for longer duration. Moreover its peel is stronger as compared to other although its pulp is soft inside. *Dhusrey* is not much preferred by consumers as its peel cracks and has poor presentation.

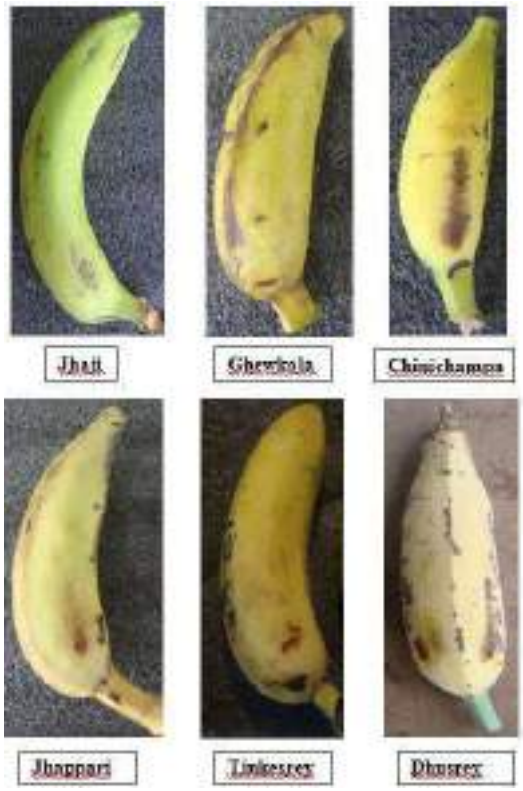

Figure 12. Appearance of fingers of six Varieties

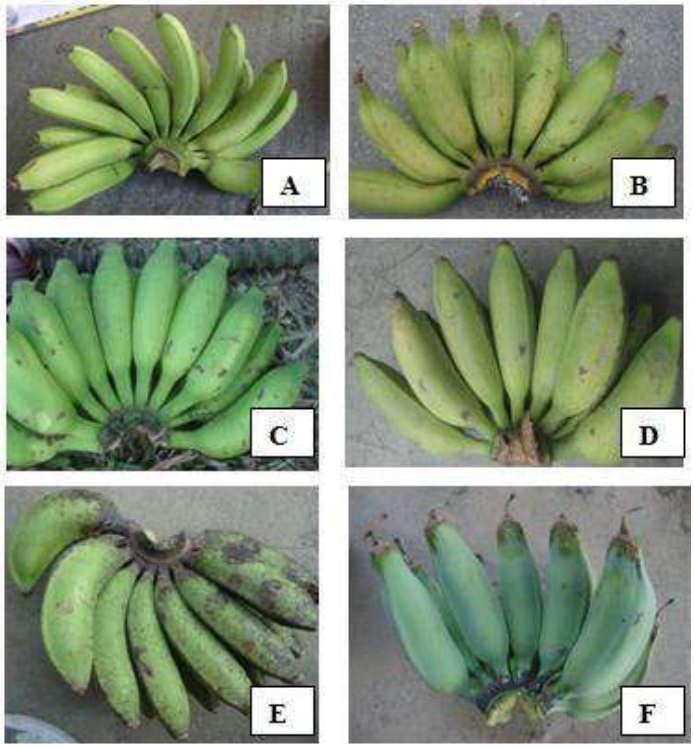

Figure 13. General appearance of hands of six varieties (A = Jhaji, B = Ghewkola, C = Chinichampa, D = Jhappari, E = Tinkesrey and F = Dhusrey)

Table 3. Frequency distribution of qualitative characters of six banana varieties

Descriptors	Characters	Varieties*	Frequency	%
Leaf habit	Erect	1	1	16.67
	Intermediate	3,4	2	33.33
	Drooping	5,6	2	33.33
Dwarfism	Normal	2,3,4,5,6	5	83.33
	Dwarf type	1	1	16.67
Sap colour	Watery	1,2	2	33.33
	Milky	3,4,5,6	4	66.67
Petiole margin	Winged and clasping the pseudostem	1,2		33.33
	Not winged and clasping the pseudostem	3,4,5,6	4	66.67
Bunch position	Hanging vertically	1,6	2	33.33
	Slightly angled	3,4,5	3	50.00
	Hanging at angle 45°	2	1	16.67
Bunch shape	Truncated cone shape	2,5	2	33.33
	Cylindrical	1,2,4,6	4	66.67
Bunch appearance	Lax	2,5	2	33.33
	Compact	1,4	2	33.33
	Very compact	3,6	2	33.33
Rachis position	Falling vertically	1,4,5,6	4	66.67
	With a curve	2,3	2	33.33
Rachis appearance	Bare	3,4,5,6	4	66.67
	Neutral flowers	2	1	16.67
	Neutral/male flowers and presence of withered bracts	1	1	16.67
Colour stripes on bract	Without discoloured lines (not ridges) on the external face	3,4,5,6	4	66.67
	With discoloured lines or stripes on the external face	1,2	2	33.33
Bract behavior before falling	Revolute	2,3,5,6	4	66.67
	Not revolute	1,4	2	33.33
Male flower behavior	Falling before the bract	3,4,5,6	4	66.67
	Falling after the bract	2	1	16.67
	Neutral / male flowers persistent	1	1	16.67
Style shape	Straight	1,2,4,5,6	5	83.33
	Curved at the base	3	1	16.67
Fruit position	Curved upward (obliquely, at a 45°angle upward)	1,3,4,5,6	4	66.67

	Perpendicular to the stalk	2	1	16.67
Fruit apex	Blunt-tipped	1,5	2	33.33
	Bottle-necked	2,3,4,6	4	66.67
Remains of flower relicts at fruit apex	Persistent style	6	1	16.67
	Base of the style prominent	1,2,3,4,5	5	83.33
Adherence of the fruit peel	Fruit peels easily	1,3,4,5,6	5	83.33
	Fruit does not peel easily	2	1	16.67
Cracks in fruit peel at maturity	Without cracks	1,2,3,4,5	5	83.33
	Cracked	6	1	16.67
Fruits fall from hands	Persistent	2	1	16.67
	Deciduous	1,3,4,5,6	5	83.33
Flesh texture	Firm	1,3,4,5,6	5	83.33
	Soft	2	1	16.67

Varieties*: 1.Jhaji, 2. Ghewkola, 3. Chinichampa, 4. Jhappari, 5. Tinkesrey, 6. Dhusrey

4. Conclusion

There were similarities and differences in morphological and compositional characters among six varieties of banana. Regarding pseudo-stem, flower and leaf appearance, all the varieties were similar. Through cluster analysis looking at general quantitative morphological characters, they were grouped into four. Generally, Jhaji had different characters in terms of chemical composition of fruit pulp while rests were similar. Jhappari had comparatively maximum pseudo-stem height and diameter while Jhaji was the shortest plant. Tinkesrey had the minimum pseudostem diameter among six varieties. The leaf blade length was similar while there was significant difference in leaf blade width and petiole length among varieties. Jhaji had maximum leaf blade width with shortest petiole. Dhusrey had minimum leaf blade width and Tinkesrey had longest petiole. Peduncle length was mostly similar but width was different among six varieties. Maximum peduncle width was in Jhaji while minimum in Dhusrey. There was significant difference in number of fingers per hand, finger length and finger weight but there was no difference in bunch weight among six varieties. Dhusrey had minimum number of fingers per hand with longest and heaviest fingers but minimum bunch weight. Jhaji had maximum number of fingers per hand with minimum finger weight. Shortest finger was in Ghewkola. Highest bunch weight was in Jhaji. Bunch weight was correlated with peduncle width and number of fingers per hand.

Compositional characterization showed that Jhaji was different from other varieties which had maximum pulp pH, minimum dry matter content and maximum ash content. Dhusrey was different from other varieties with minimum pulp pH, maximum dry matter content and maximum TSS. Highest protein was found in Ghewkola. Qualitative characters showed some variations and similarities among six banana varieties. Jhaji is dwarf type with erect leaves while Chinichampa and Jhappari had intermediate leaves and Ghewkola and Dhusrey with drooping leaves. Jhajiand Ghewkola had watery sap with winged petiole margin but others had milky sap without winged petiole margin. Bunch position was at 45^{o} angle in Ghewkola,

hanging vertically in Jhaji and Dhusrey and at an angle in Chinichampa and Chappari. Jhaji bear neutral or male flower with presence of withered bracts, ghewkola with neutral flowers and others have bare rachis. Jhaji and Ghewkola had colour stripes on bract while rest of the varieties did not have. The behaviour of bract before falling was non revolute in Jhaji and Jhappari while revolute in other varieties. Male flower remain neutral or persistent in Jhaji while male flowers fall after the bract in Ghewkola but fall before the bract fall in other varieties. Chinichampa had style with curved at the base. Ghewkola had fingers on the bunch at perpendicular to the stalk while rests were curved. Dhusrey had persistent style at the finger tip and cracked peel while others had prominent base of style without cracked peel. Fruit apexes were blunt tipped in Jhaji and Tinkesrey while rest had bottle neck type. For future studies characterization of wild bananas would contribute to diversification of genotype and species for future germplasm collection and breeding purposes. Study on physicochemical characters for different varieties in same location and same variety in different locations is essential.

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Phenotypic Characterization of Common Bean Landraces from Eastern Bhutan and their Potential Use

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ABSTRACT

Common Bean (Phaseolus vulgaris L.) is one of the most important leguminous crops which have global adaptability and phenotypic diversity. It is also used for human consumption worldwide. It constitutes major source of protein, complex carbohydrates and micronutrients. In Bhutan, diverse types of beans are found and are an important source of income and food security for large section of the society. However, not many studies have been carried out to document the characteristics of this diverse crop. Hence, phenotypic characterization of local germplasm from eastern Bhutan was carried out to conserve the existing rich germplasm and exploit them for potential use in future. Out of more than fifty-two accessions, fifteen were selected and on-station field trial was established using randomized complete block design with three replications to assess phenotypic characteristics. Phenotypic characteristics were recorded following the UPOV standards. As expected, significant phenotypic variation was observed between determinate and indeterminate types regarding number of pods per plant, yield per plant and weight of dried seeds. The accessions also differed considerably in terms of seed weight. The cluster analysis based on 14 parameters allowed identification of beans into two large groups and four sub-groups. In terms of yield, accessions 24 and 27 recorded significantly higher yield than the others.

Keywords: *Common Bean; Phenotypic characteristics; Eastern Bhutan; Potential use*

1. Introduction

Common bean demonstrates a global adaptability, phenotypic diversity and is believed that cultivated common bean originated from the wild species *Phaseolus aborigineus* (Vidak et al 2015). Common bean is a major source of protein, complex carbohydrates, and micronutrients; the common bean is also one of the most important crops for human consumption worldwide (Broughton et al 2003).

Bhutanese diet is often dominated by carbohydrate rich crops like maize, rice, and potato that are poor in protein content. According to Blair et al (2003) eggs, milk and meat are primary source of proteins which can be substituted by leguminous crops like beans and peas. Dry beans contain high levels of chemically diverse components (phenols, resistance starch, vitamins, fructo-oligosaccharides) that provide protection against oxidative stress, cardiovascular disease, diabetes, metabolic syndrome, and many types of cancer positioning this legume as an excellent functional food (Schlegel 2013).

Beans, along with maize used to constitute staple diet for large part of eastern Bhutan. For instance, in early 1980s people used beans as staple food mixed with maize grits or often with bean porridges (Wangdi 2016). Common bean species may not be native to Bhutan yet

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through naturalization greater diversity of crop varieties are found ranging from subtropical to temperate regions. This commodity represents age old country's rural farming pattern having best compatibility with maize. Hence, bean has become an element of cultural identity comparable with other crops like rice, maize and chilli (Dopola 2016).

However, lately, once beans rich place like Jurmey in Monggar has seen a decline in bean diversity due to change in food habits and modern farming systems with advent of rapid social economic development in the country. In many countries landraces are replaced by exotic crop through intervention by various agencies and departments through crop promotional program (CPP) and other commercial activities. For example, Giulia Paniconi (2010) mentioned that in country like Italy landraces dropped considerably in number from the National Register, due to lack of commercial interest from major seed companies that focused on the breeding of preferred few types by the market. Hence, there is a similar risk to our landraces as well. Krasteva et al (2002) expressed that conservation, study and use of local plant resources is a basic problem for breeding in many countries. In Bhutan, National Biodiversity Centre (NBC 2008) reported about 51 traditional varieties of beans as per oral report by farmers. However, till date, no phenotypic and morphological characterization has been reported, which is a crucial missing link in germplasm conservation strategies. Hence, Agriculture and Research Development Centre (ARDC) at Wengkhar initiated collection and characterization of existing beans landraces from Eastern Bhutan. It would provide valuable information and germplasm to agricultural researchers and other users. Further, landrace crop can contain phenotypic and genotypic variability that can be exploited to develop new lines (Abu-Amer 2011).

2. Materials and methods

Fifty-two cultivars were collected from different villages in Eastern Bhutan from April to May 2015. These were collected from various eastern ecological regions. Out of fifty-two, fifteen accessions (Table 1) were selected based on visual seed shape and color. On-station multiplication of selected samples was carried out from Jul-Oct 2015 for this study.

The study was conducted at Agriculture Research and Development Centre, Wengkhar, Mongar Bhutan. Seeds were sown in open field using randomized complete block design with 3 replications. A spacing of 0.5 meters between rows and 0.35 meters between plants was maintained. Irrigation was provided after sowing and thereafter depending on soil moisture through hand-feel method. Farm yard manures and fertilizers were applied as per the recommended practices for common beans. Experimental plots were covered with net to protect against birds during germination. Plants were protected against pests and fungal diseases with cypermethrin and Anvel (hexaconazole EC 10 and 5%; Syngenta, India) at 1 ml l:1. Hand weeding between and within rows was continued throughout the growing season.

Table 1. Accessions of common beans used for phenotypic characterization

Accession no	Place of collection	Accession name
13	Gomchu	Yadhipa Orey
06	Kerong	Orey Regtang
29	Laneree	Tulumpee Orey
38	Laneree	Orey Balingmin
12	Gomchu	Yadhipa Orey
08	Nanong	Zangki Orey
07	Kerong	Kerongree Orey
11	Gomchu	Orey Changlu
24	Kerong	Pinkulung Orey
27	Nanong	Orey Serbu
01	Tsamang	Shepen
03	Laneree	Orey
15	Kanglung	OreyBrokchilu
25	Tsamang	Brokpali
34	Norbugang	BorangmoOrey

From each plot, 10 plants per replication were randomly chosen for biometric measurements. Observations were made for 14 morphological characteristics as per the International Union for the Protection of new Varieties of plants (UPOV) guidelines : (1) days from sowing to flowering, (2) days from sowing to maturity, (3) average height of the pods, (4) biological yield, (5) number of pods per plant,(6) weight of pods per plant, (7) pod length, (8) pod color, (9) pod shape of distal part including beak, (10) pod curvature beak, (11) weight of seeds, (12)) terminal leaf shape, (13 seed coat color, (14) seed shape of medium longitudinal section (Table 2).

Data were analyzed using IBM SPSS version 22. For mean yield, number of pods and seed weight comparison, one-way ANOVA method was used. Multiple comparisons among the accessions were done using Duncan's Multiple Range Rest. The hierarchical cluster analysis method was used to construct dendrogram for categorization of the accessions.

Table 2. Morphological characteristics used in the study

Traits(Variables)	Growth stage
Leaf-Terminal leaf Shape	Fruiting
Leaf-Terminal leaf Apex	Fruiting
Pod – degree of curvature	immature pods (10 pods)
Pod – ground color (immature)	immature pods (10 pods)
Pod-shape	immature pods
Pod-Shape of Distal Part-Including Beak	immature pods
Pod-Curvature of Beak	immature pods
Pod- weight of Pod(gm.)	immature pods(10 pods)
Pod- Height of Pod (cm)	immature pods(10 pods)
Seed- Seed Coat colour	dried seed
Seed- Seed weight(gm)	100nos
Seed-Shape of median Longitudinal section	Dried seed
Vegetation period	from sowing to beginning of flowering (days)
Days of flowering	50% flowering from beginning of germination (days)
Vegetation period	from sowing to seed maturity (days)

3. Result and discussion

Common beans are largely grouped into two categories: Determinate and Indeterminate types. Determinate types are those that do not need staking to support their growth. Indeterminate types are climbers that require support in the form of staking to grow up. In Bhutan, among the two, indeterminate types are found in more abundance.

Among the indeterminate types, performance of accession number 24 and 27, in terms of yield, was significantly higher than most of the accessions whereas accession number 11 recorded the lowest of all. Accessions number 24 and 27 have the potential to produce 7.7 ton/acre whereas accession 11 can produce just about 1.2 ton. As in yield, accessions 24 and 27 had the highest numbers of pods per plant and accession 11 the least. In terms of seed weight, accessions number 12 has significantly higher than rest of the accessions, and accession 38 the least (Table 3).

Figure 1. Pods of different accessions

Figure 2. Seeds of different accessions

Table 3. Comparison of mean yield, number of pods and dried seed weight among indeterminate

Accession no	Mean yield/ plant (gm)	No of pods	Dried seed weight (gm.)
13	140.9a	26.8a	0.51g
06	161ab	36.8ab	0.26a
29	279.4abc	33.6ab	0.34d
38	279.5abc	22.0a	0.25a
12	289.7abc	35.4ab	0.69i
08	314.7bc	52.0bc	0.46f
07	315bc	38.8ab	0.30b
11	53.6d	19.4a	0.32c
24	331.4c	64.0c	0.60h
27	331.4c	59.8c	0.42e

The mean values in the table with same letter between the accessions indicates lack of statistically significant difference at 95% confidence level

Among the determinate types, accession number 1 had significantly higher yield whereas accession number 3 had the least. Accession 1 can produce as high as 4.4 ton while 3 can produce only about 1.5 ton per acres. In terms of pods per plant, accession 15 had the highest followed by 1 and 34 and the 3 the least. Accession 1 had the highest seed weight followed by 15 and 3 (Table 4).

Table 4. Comparison of mean yield, number of pods and dried seed weight among determinate

Accession no	Mean yield per plant (gm.)	No of pods	Dried seed weight (gm)
01	191.9c	22.2bc	0.70d
03	70.1a	10.8a	0.46b
15	159.2bc	23.2c	0.47b
25	64.6a	14.8ab	0.56c
34	136.9b	19.0bc	0.40a

Figure 1 depicts a dendrogram based on the hierarchical cluster analysis. The horizontal axis of the dendrogram measures dissimilarity among the entities. The analysis categorizes the accessions into two large groups at the top and about five sub-groups at the lower level. Though the number of accessions used for the study is fairly small, the number of cluster is relatively large indicating there could be wide range of beans diversity in the country.

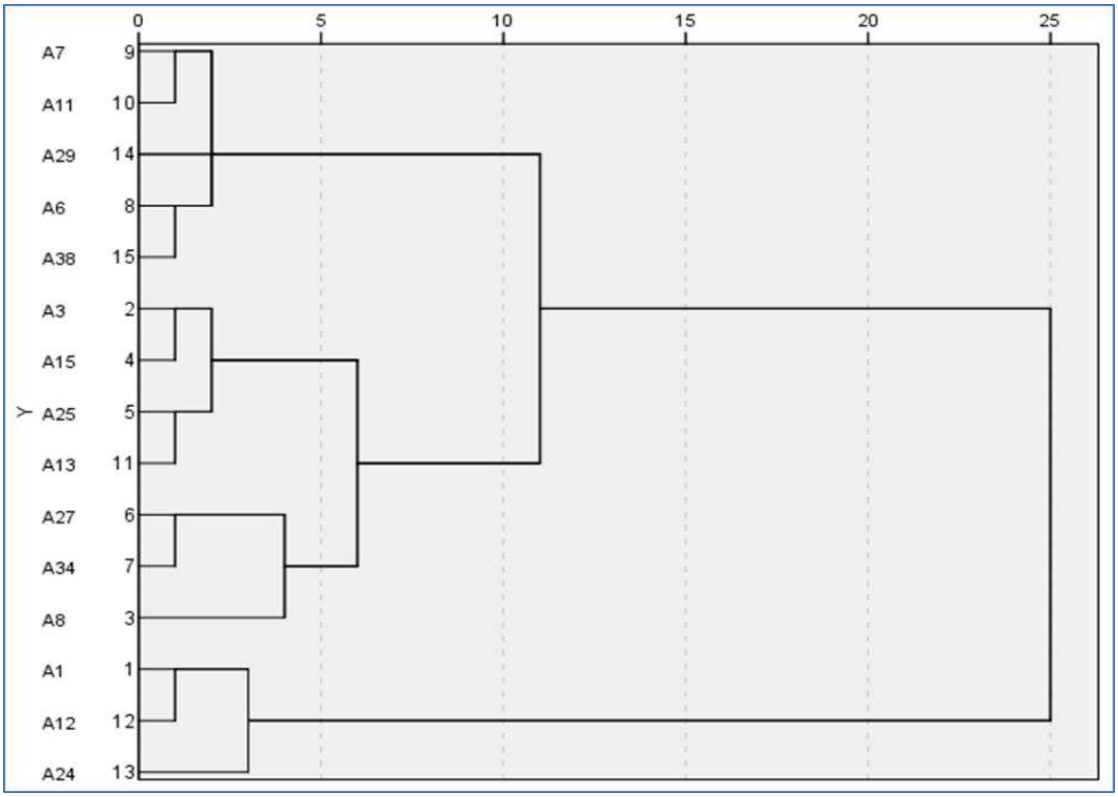

Figure 3. Dendrogram using average linkage between groups

4. Conclusion

The effort to study common bean diversity is one of the first in the country though beans were largely used in Bhutanese diets for ages. Common beans have vital role both in terms of food and nutrition security besides potential for income generation. Characterization and conservation of landraces have many benefits. Evaluation of quantitative and qualitative traits gives the possibility to choose and include the most adapted accessions in future breeding activities or to conserve and use them for production with high quality. Among the indeterminate types, accession number 24 (Pingkulung Orey from Kerong village) and 27 (Orey Serbu from Nanong village) were found to be most productive. Similarly, from determinate type, accession number 1 (Shepenorey from Tsamang village) and 34 (Borangmoorey from Norbugang village) were most productive. The cluster analysis shows lots of diversity even within the limited number of accessions indicating the greater potential for beans diversity in the country. Overall, the study provides a kind of springboard to further enhance research especially to characterize, document, conserve and judiciously utilize often underutilized rich agro-biodiversity in the country.

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Social Capital cultivates "Fruits of Happiness" in Eastern Bhutan

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ABSTRACT

Bhutan is an agrarian economy where agriculture sector provides employment to about 58% of the total employed persons. However, farmers were found to be the least GNH happy from the result of the 2015 GNH Survey conducted by the Centre for Bhutan Studies and the Gross National Commission with assistance from Japan International Cooperation Agency (JICA). In order to improve this sector, the Royal Government of Bhutan (RGoB) in collaboration with JICA implemented a five-year horticulture project t(2010-2015) called Horticulture Research and Development Project (HRDP) covering six eastern dzongkhags. Based on the secondary data of HRDP-GNH Survey 2016, this paper aimed at studying the impacts of the project on the three dimensions of social capital – bonding, bridging, and linking social capital at both micro and macro level linkages. Quantitative data indicated that HRDP has made a significant impact on social networks, norms of reciprocity, social trust and identity, and numerous forms of social contribution. In effect, these results can play a vital role in the project's long term success since the project is in its early life-cycle stage. Based on the results of this study, it is recommended that future agriculture projects apply the social capital oriented approach of HRDP to enhance farmers' happiness in the country.

Keywords: *GNH, Social capital (Bonding, Bridging and Linking)*

1. Introduction

JICA in collaboration with the Ministry of Agriculture and Forests started the horticulture research and development project (HRDP) in 2010 with the main aim of making horticulture more popular as a source of income in the six eastern dzongkhags (RNRRDC 2014). More than 40 varieties of fruits and vegetables were cultivated by more than 750 farmers across more than 2,000 acres of land through careful hands-on training, on the basis of mutual understanding and trust. The project ended in 2015. It is considered as one of the most successful projects of JICA in Bhutan.

The technical evaluation report as well as a GNH based evaluation found significant positive impacts of the project. Despite the project being in the early life-cycle stage, results showed a significant impact on living standard, mental health, social capital, and emotions from the standpoint of people's happiness (Phuntsho 2017). This paper is an attempt to further discuss how the different dimensions of social capital were impacted and how they contributed to the success of the project towards the ultimate aim of enhancing farmers' happiness. It goes beyond the scope of the former report by delving into social capital indicators which are not part of the GNH index[aa].

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Social capital is understood in different ways. Putnam (1995, p. 67) has defined it as 'features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit'. Lin (2001), for instance, has described social capital as 'investment in social relations with expected returns in the marketplace'. In more general terms, social capital is defined by the OECD as 'networks together with shared norms, values and understandings that facilitate co-operation within or among groups' (OECD n.d.). Social network relations are 'capital' in the sense that 'they provide access to a variety of goods and services, such as information, the pleasure of social interaction, or social exchange opportunities' (Whitham 2012). Further debate exists over whether social capital is an individual or solely a community concept or a function of both. To this, Megyesi, Kelemen and Schermer (2010) considered social capital as 'the property of the individuals, but only by virtue of their membership in a group'. On the other hand, Hawkins and Maurer (2010) contend that it is in the focus on the actions of individuals in relation to structural forces (their community) that the framework of social capital finds its greatest usefulness in social work. There is no universally accepted concrete definition of social capital but what is overwhelming is, there has been a proliferation of academic works on the subject. It is being empirically proven that social capital plays a vital role in happiness (Choden 2016), sustainable economic growth (Rupasingha et al 2000), health (Kitchen et al 2012; Song 2010), sustainable development (Vera-Toscano et al 2013), etc. Lin (2001) offers four explanations as to why social capital plays a very decisive role not accounted for by forms of personal capital such as economic or human capital. These four elements in short are information, influence, social credentials, and reinforcement.

In the agriculture sector too, there is a lot of focus on social capital. According to Vera-Toscano et al (2013), farmers often form part of one or several associations to defend their general interests (as occurs with professional organizations, also called farmers unions), to articulate their specific interests as producers tied to a particular type of agricultural or livestock production, to purchase inputs or commercialize their products (as is the case of cooperatives), to mediate in the regulation of markets (such as organizations of producers),to ensure the quality of production in certain sectors, etc.

2. Materials and Method

This paper uses the theoretical framework proposed by Megyesi et al (2010) to explain the roles of bonding, bridging, and linking social capital in the project's success. The social capital typology shown in Table 1 is adapted from their work.

The paper is based on the secondary data of HRDP-GNH survey conducted in 2016. The sample constitute of 47 beneficiaries[bb] and 196 comparable[cc] non-beneficiary farmers. Due to

[bb] A total of 64 beneficiary farmers were interviewed but only 47 of them have started reaping the benefits of the project. This was taken as the final sample of beneficiary farmers in the HRDP-GNH report

[cc] A screening questionnaire which consists of seven variables has been used to select the comparable non-beneficiary farmers. Matching using PSM retained all 196 of them.

small sample size, only descriptive statistics has been used. Chi-square test of association and independent samples t-test were used to test statistical significance[dd] of the results.

Indicators used for each of these social capitals are as follows[ee]:

Bonding social capital: trust, sense of belonging, frequency of socialization, social support, volunteerism, cultural participation, and donation

Bridging social capital: skill and knowledge transfer, generalized trust, ties to markets and resource persons

Linking social capital: participation in *zomdue,* voting, connection to formal institutions, trust in institutions

Table 1. Social capital typology

Macro	Synergy	Organizational integrity
	Ties connecting the representatives of HRDP to formal institutions – government and other organizations involved in it	Trust and credibility of the formal institutions and their capacity to provide the services effectively
	Linking/Bracing social capital Linkages between members of HRDP and government officials, decision makers, development partners, and the market	
Micro	Bonding social capital	Bridging social capital
	Ties within the members of the project and in the local community	Ties with people outside the HRDP project and other communities

3. Results and Discussion

Bonding social capital refers to the social capital generated through the interaction between members of a relatively homogenous group (Vera-Toscano et al 2013). Putnam (2000) suggests that bonding social capital can be used 'to help people meet their basic needs in a mutually beneficial manner by bringing people together who are similar in some respect'. HRDP has made significant impacts on various indicators of bonding social capital. It was found that the percentage of respondents who reported their sense of belonging to the local community as 'very strong' is statistically significantly higher among the beneficiary farmers (83%) as compared to non-beneficiary farmers (62.2%) (Table 2). Sense of belonging is a very important indicator of social capital. A person with high sense of belonging is more likely to cooperate with other members of the community. In fact, Kitchen et al (2012)

[dd]For the purpose of this study, null hypothesis is accepted (i.e. relationship between two variables are considered significant) if p-value is less than or equal to 0.1.

[ee] Indicators were selected from the works of Kitchen et al (2012), Vera-Toscano et al (2013), Megyesi et al (2010).

pointed out that social capital is closely related to the concept of sense of belonging. This variable is comparable to local identity of members (found in Megyesi et al 2010).Level of trust towards one's neighbor is also higher among the beneficiary farmers but the difference is not statistically significant (Table 3). However, community relationships[ff], which is an aggregation of the former two variables was found to be statistically significant (Phuntsho 2017, p. 43). Such positive results may have occurred as a result of the higher frequency of interactions they make with people in their neighbourhood (Table 4). In addition, social support which is measured in terms of the number of people they can count on during the times of sickness, financial problems, emotional problems, and important personal events such as childbirth, funeral, wedding, etc. are being assessed. This is similar to the concept of reciprocity. There is a high correlation with the number of people whom you lend support to and who lends support to you in return. Results show that the average number of people they can count on during such times is substantially higher among farmers who have joined the project (Table 5) thus indicating a better network of people whom they could rely upon during times of need. Skill transfer rate refer to the average number of people to whom they have transferred their knowledge and skill gained after attending the trainings provided by the project. Project evaluation report conducted in 2015 showed that the skill transfer rate among farmers who attended the training is 6.4 persons[gg] (RNRRDC 2014). Within a period of less than five years, this is an impressive number. Other objective indicators[hh] of bonding social capital include the amount of donation, number of days volunteered, and number of days engaged in socio-cultural events in the community. Consistent with the earlier findings, beneficiary farmers were found to be significantly better in all these indicators (Table 6; Table 7; Table 8).

Table 2. Sense of belonging to the local community

	Non-beneficiary	Beneficiary	Total
Weak	0.5%	4.3%	1.2%
Somewhat strong	36.7%	12.8%	32.1%
Very strong	62.2%	83.0%	66.3%
Don't know	0.5%	0.0%	0.4%
Total	100%	100%	100%

Pearson chi2(3) = 13.7914, p= 0.003

[ff] This is one indicator under community vitality in the computation of GNH index (Ura, Alkire, Zangmo, & Wangdi 2012).

[gg]One of the key objectives of the project is to enhance the project's impact through their trained farmers by extending their skills to others. In the project assessment report, it was mentioned that 656 farmers have been trained till September 2014 and 86.2 percent of the trained farmers have extended their skills to others till March 2014 (RNRRDC 2014).

[hh] Kitchen, Williams and Simone (2012) has termed such variables as social capital 'actions'. Volunteering is one of the indicators used by them

Table 3. Trust towards neighbour

	Non-beneficiary	Beneficiary	Total
Trust none of them	1.5%	2.1%	1.6%
Trust a few of them	18.9%	10.6%	17.3%
Trust some of them	51.5%	42.6%	49.8%
Trust most of them	28.1%	44.7%	31.3%
Total	100%	100%	100%

Pearson chi 2(3) = 5.5326, p= 0.137

Table 4. Frequency of socialization

	Non-beneficiary	Beneficiary	Total
Not in the last month	12.2%	8.5%	11.5%
Once a month	9.2%	4.3%	8.2%
Few times a month	55.1%	53.2%	54.7%
Few times per week	23.5%	34.0%	25.5%
Total	100%	100%	100%

Pearson chi 2(3) = 3.2638, p= 0.353

Table 5. Social support

	Non-Beneficiary	Beneficiary	d.f.	t	p-value
Important personal events	16.9	26.8	239	-3.1991	0.0016
Sickness	5.4	7.5	241	-1.4572	0.1464
Emotional problem	7.5	7.6	240	-0.0676	0.9461
Financial problem	32.8	46.1	236	-3.1086	0.0021

Table 6. Number of days volunteered

	Non-beneficiary	Beneficiary	Total
	9.67	15.77	10.85

t(241) = -1.9537, p = 0.0519

Table 7. Donation

	Non-beneficiary	Beneficiary	Total
	4974	9233	5798

t(241) = -2.5857, P = 0.0103

Table 8. Participation in socio-cultural activities

	Non-beneficiary	Beneficiary	Total
	14.32	18.57	15.14

t(241) = -1.7975, p= 0.0735

These indicate that the project has made a significant impact on bonding social capital. What may be some possible reasons for that? First, the project focused on group activity. Some cooperatives were also formed. Most beneficiary farmers are enrolled under the focus-village approach[ii]. Under this, all selected farmers in the village grow same horticulture crop. A village representative attends the training at the project base in Wengkhar and he/she is responsible for disseminating the knowledge and skill to other members of the project in the village. In other approaches too, there are mentions of group learning and peer-to-peer knowledge sharing. Second, according to many beneficiaries, horticulture has become a part of their identity: a well-regarded activity and a ground for common interests. Many pride themselves of having joined the project and found an alternative means to support their livelihood in the village. Such characteristics of bonding to one's community are vital in order to sustain and spread the benefits of the project.

Bridging social capital refers to connections with other non-members of the community, members of other communities, resource persons, funders, and markets. Such linkages are important for mobilization of external resources and other forms of capital. One important aspect of bridging capital is the linkage between farmers who have joined the project and the coordinators and the resource persons of the project, such as technical experts, trainers, and supervisors. On this aspect, HRDP is the most advanced agriculture project so far (Phuntsho 2016). Most government interventions are limited to the supply of seed and other resources. The main distinctive feature of HRDP is that so much emphasis has been laid on skill and knowledge transfer through actual learning. For instance, farmers under systematic training and orchard development approach spend months at Wengkhar undergoing training, starting from pit digging to post-harvesting to food processing through the practice of leaning-through- working together, directly receiving advice from Japanese and Bhutanese horticulture experts. Farmers who have joined the project in general were found to have close ties with the project coordinators. Project coordinators visit their fields frequently in person to investigate the progress as well as to explore ways for further improvement. So far as connection to markets is concerned, the farmers have not started selling fruits in large quantities. However, beneficiary farmers have made a significant amount of cash income from the sale of vegetables as compared to those who have not joined the project (Phuntsho 2017, p. 42). In addition to that, the project enhanced farmers' groups in marketing of their products. Project evaluation report mentioned that overall about 96.3% of the groups in which the trained farmers joined have started to take their produce to the markets. To what extent does a person trust other people in general, often termed as generalized trust, is an important aspect of civic culture. Survey showed that farmers who have joined the project had a higher level of generalized trust (Table 9) but the difference is not statistically significant.

[ii] There are three different approaches under HRDP: (i) systematic training and orchard development, (ii) focus-village development approach, and (iii) direct support programme.

Table 9. Generalized trust

	Non-beneficiary	Beneficiary	Total
Trust none of them	3.6%	8.5%	4.5%
Trust a few of them	57.1%	42.6%	54.3%
Trust some of them	32.7%	40.4%	34.2%
Trust most of them	5.1%	8.5%	5.8%
Don't know	1.5%	0.0%	1.2%
Total	100%	100%	100%

Pearson chi2(4) = 5.6829 p= 0.224

Linking social capital is very similar to bridging social capital. The only difference is, the latter refer to ties with individuals or groups that belong to, or linkages with people or groups in a position of political or financial power (Vera-Toscano et al 2013). This aspect is measured by participation in meetings and voting. Participation in meetings (*zomdue*) is an important forum to connect with decision makers and local leaders. In the past one year, only 6.4 percent of beneficiary farmers have not attended a *zomdue* as compared to 11.2 percent of non-beneficiaries (Table 10). Proportion of individuals who have voted in the last Local Government (LG) election is also higher among the beneficiary farmers (Table 11). The difference is not significant though.

Table 10. Participation in *zomdue*

	Non-beneficiary	Beneficiary	Total
No	11.2%	6.4%	10.3%
Yes	88.8%	89.4%	88.9%
Not applicable	0.0%	4.3%	0.8%
Total	100%	100%	100%

Pearson chi2 (2) = 9.2056 p= 0.010

Table 11. Voted in last LG election

	Non-beneficiary	Beneficiary	Total
Yes	73.0%	76.6%	73.7%
No	12.8%	6.4%	11.5%
Not applicable	14.3%	17.0%	14.8%
Total	100%	100%	100%

Pearson chi2(2) = 1.5954 p = 0.450

At the macro-level, social capital is discussed in terms of synergy between members of the project and concerned formal institutions, and perceptions of organizational integrity. This paper identifies two key institutions of interest to the HRDP project: the government and the development partner (JICA). His Majesty the King, in recognition of the project's success and its significant contribution to the lives of people in the eastern dzongkhags, have awarded National Order of Merit Gold to two key persons who spearheaded the project. It is obvious that this initiative by the King will play a very significant role in the success of the project since the project is still in the early life-cycle stage. On behalf of the Ministry of Agriculture and Forests, HRDP is being handled by RNRRDC located at Wengkhar in Mongar

Dzongkhag. The centre is one of the biggest agriculture research and development centre in the country. The location of the centre at the heart of six dzongkhags makes it even more accessible to the farmers. From JICA's part, the team was led by Tomiyasu who has an experience of 20 years of working in horticulture project in Nepal and 17 years in Bhutan.

4. Conclusion

The findings reveal that HRDP project has made significant impacts on different dimensions of the social capital. It can also be argued that different forms of social capital have contributed significantly to the success of the project. The products of the project became well known as the "Wengkhar Brand" –a token of trust. Megyesi et al (2010) have concluded that bonding social capital is an essential ground for bridging and linking social capital. This is evident in the present case also where strong trust, local identity, cooperation and greater contributions towards the community have created enabling conditions for establishing successful ties with outside actors like the government, decision makers, development partners and markets. But from this particular case, it may be concluded that the macro level synergy, organizational integrity, and project modality have played an equally, if not more, important roles in achieving the success of the project. The ability to link Japanese expertise, product viability, and effective delivery model together contributed to success of the project. Had this project not been implemented by JICA and RNRRDC in the present form, success at this level is not expected, especially on social capital. Therefore, in the agriculture sector, it is suggested that future projects embody the salient features of HRDP – social capital. Farmers were found to be the least happy among other occupational groups in the 2015 GNH survey. In order to alleviate farmers' unhappiness, social capital must be one key point.

In future, a quantitative study to explore the dynamics of inter-linkages between different indicators and dimensions of social capital is recommended. Whether social capital leads to better economic and social conditions including happiness of the farmers is also an interesting question to be pursued. The current study suffers from small sample size and such analysis was not attempted.

Acknowledgements

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Guidelines for Authors

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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Manuscripts submitted to the Bhutanese Journal of Agriculture should strictly conform to the following instructions and technical guidelines:

Total length of the article:

Maximum **5000-7,000** words including spaces and list of references for full length articles and **2000-4000** words for short communication.

Title

The first page of each manuscript starts with the title of the paper which should be typed in bold-faced print using both upper and lower case letters and set in the centre of the page. The title should be as concise and catchy to reflect what the paper is all about? Abbreviations are not permitted in the title. The title should be in Times New Roman with **14** point bold.

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.

The term "**Keywords**" is typed in bold-faced print followed by a colon. The first letter of each key word is capitalized and key words are separated by semicolon. Keywords should include the main attributes of your papers; should be between 3-5 keywords; font **12** point italic, Times New Roman.

Example:

Keywords: *Aeroponics; cultivars; planting time; potato mini-tubers**;** winter*

Introduction

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.

General:

Study area, location and their description must be given with illustration if possible. Authors may supply latitude and longitude coordinates for the study area/location referred to. For any

equations used in the papers, standard equation format should be followed. Equations must be numbered and placed directly in the text with serial number. Figures, tables, and boxes must be referred to in the text, in numerical order.

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.

Results and Discussion

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.

Conclusion

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 done 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.
- Tables should be inserted as enhanced metafiles
- No border lines, only boundary lines will be used, 10 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
Control	93	21	9.8	108
CV (%)	23.5	12	15.7	22.3
F Value	**	*	***	*

Figures

- Possible file formats: .JPG, PDF, .XLS, .GRF.
- The figures should be inserted as enhanced metafiles
- 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)

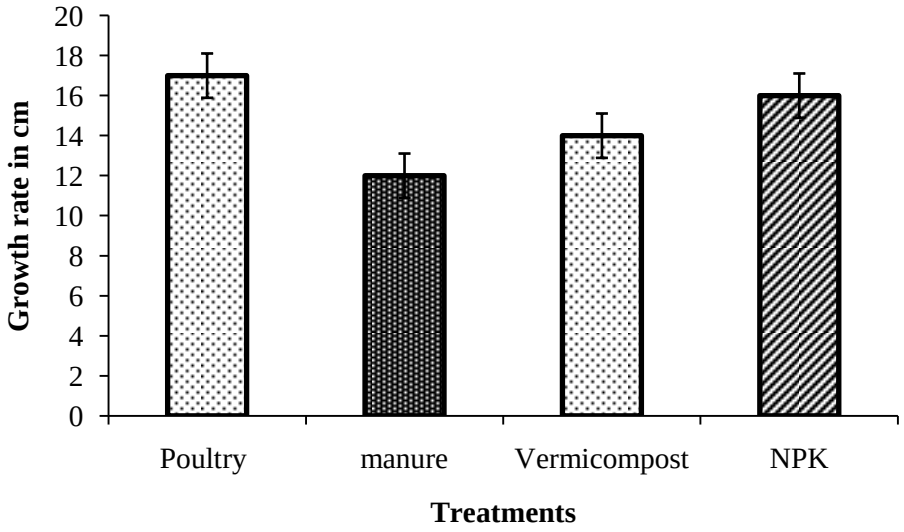

Figure1. Effect of treatments on growth rate of broccoli plant

Referencing

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.

General rule

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 for in-text citation:

- Karma (1993, 1995a, 1995b)
- Yuden and Dorji (2004)
- (Sonam et al 1975)
- (Sonam 1997)
- (Stremlow 1998; Antrop 1999; Tress and Tress 2001; Backhaus et al 2007a, 2007b)
- (see figures 4 and 5 in Keen et al 1971)
- Campbell (1993: 55);

Reference

- 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
- Always provide city and country of publication, e.g. "Thimphu, Bhutan
- Use English version of cities and other place names

- All items listed under References must be publicly available, i.e. in a library or on the Internet; personal communications, or unpublished data can be included; exception: unpublished articles can be listed if you provide an address at which a copy can be requested; ideally, this will be your own address; example: "available from corresponding author of this article"
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- References should contain: **author's last name** followed by **author's initial** (s) with **periods**, **year**, and **title of article**, volume and inclusive page numbers. **Book and reports** must include the name and location of the publisher: Please see the following examples.

Journal article

Farran I, Angel M. & Mingo C. 2006. Effects of potato plant density and harvesting intervals in aeroponics. *American Journal of Potato Research.* 83: 47-53

Mingo C. 2006. Effects of potato plant density and harvesting intervals in aeroponics. *American Journal of Potato Research.* 83: 47-53

Grau H.R., Aide T.M. 2007. Are rural–urban migration and sustainable development compatible in mountain systems? Mountain Research and Development. 27(2):119–123. http://dx.doi.org/10.1659/mrd.0906.

Journal article published online but not (yet) on paper

Dang V.H, Shively G. 2007. Coffee boom, coffee bust, and smallholder response in Vietnam's Central Highlands. Review of Development Economics, Online Early, 4 September 2007. http://dx.doi.org/10.1111/j.1467-9361.2007.00391.x.

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