Government of Nepal
Ministry of Agriculture, Land Management and Cooperatives
Food Security, Agri-Business Promotion and Environment Division
Environment and Climate Change Section
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The Journal of AGRICULTURE AND ENVIRONMENT 2018

"BEAT PLASTIC POLLUTION: IF YOU CAN'T REUSE IT, REFUSE IT"

"प्लाष्टिक प्रदुषण निर्मुल पारौं, पुनर्प्रयोग गर्न नसके वहिष्कार गरौं"

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EDITORIAL

Agriculture modernization,power generation,industrialization,urbanization, other such development works, use of natural resources for fuel,fodder, and shelter may cause degredation and exploit of the biodiversity and environment and should to consider to protect them wisely.Due to the numeraous anthropogenic activities in the globe, causes rise in temperature, change in precipitation rise in sea level, milting of glaciers, and extreme climate change events and impact on the biodiversity, environment degredation, and food insecurity.

“Beat plastic pollution: if you can't reuse it, refuse it” is the theme decleared by the United Nations Environment Program for the world environment day 2018. The world Environment Day (June 5) is an auspicious occasion for all categories of people in only the green planet. The Earth is celebrated to create awareness and to accomplish action for environment protection.Different types of plastic materials for the human life and devevelopment sectors are used for some of them causing environment pollution and degredation. So, we should use or reduce, reuse and recycle them principle.

There is interrelationship between man and other living and non-living things in the nature. Due to the interference of human in the nature, some wild species of plants and animals were found endangered and some have disappeared. When some species disappeared then it may be very difficult to revive again. So, we should preserve our environment and their importance for conserving and maintaining ecosystem and balancing nature and sustainable livelihoods of the people. We should to handover without degredation to our future generation.

The day is being celebrated through organization of several events and relevant environmental campaigns. The Ministry of Agriculture, Land Management and Cooperatives (MoALMC) is publishing the new issue of Journal of the Agriculture and Environment (Vol. 19, 2018)where technical and review articles on agriculture and environment, climate change, organic agriculture and agriculture marketing linkages and other cross cutting issues are the major coverage.

The editorial-in-chief acknowledges the valuable contribution from authors, editors, reviewers, and the editorial management team. I hope that readers will find some useful information on environment friendly agriculture. The editorial board will highly be pleased to receive valuable suggestions and feedbacks to improve in upcoming issues.

Thanks!

Editor-in-Chief

GUIDELINES TO AUTHORS: MANUSCRIPT PREPARATION AND SUBMISSION

Food Security Agri-business Promotion and Environment Division (FSED) under the MoALMC announces interested author(s) to submit relevant manuscripts for publication in every forthcoming issue of the ***Journal of Agriculture and Environment***. The author(s) should base the manuscript on issues of climate change/food security/agricultural biodiversity/gender and social inclusion (preferably in Nepalese or similar context).

Guidelines for the author(s):

The Journal of *Agriculture and Environment* is devoted to the cause of advancing understanding on the Environmental aspects of Agriculture through literature review, theoretical analysis, research and practical experiences. Besides research and review papers, the journal may arrange spaces for case study, methodological approach, book review, report on seminar and meeting, short communication and letter to the editor. Guidelines to authors on preparation and submission of manuscript as follow.

1. The manuscript must be an original work written in English and not published elsewhere.
2. The title should be short and specific, but it should reflect the contents in the manuscript.
3. The abstract should be in italics 9-point font size, not exceeding 150 words, should concisely state major objective, methodology, findings and conclusion. It should not include diagram, footnote, equation or any parenthetical reference.
4. Key-words in alphabetical order should not exceed ten standard words.
5. Main text of the technical manuscripts should include introduction, objective, theoretical framework, methodology, results and discussions, conclusions and references.
6. The manuscript should not exceed 4500 words in total. It should be in MS-word with pages set on A4 size, the top and left margins at 3cm and the right and bottom margins at 2.5cm. The text format should be on Trebuchet MS font of, unless otherwise specified, 10-point size.
    a. The title of the manuscript set as Heading 1 (paragraph style) should be all capitalized in bold 11-point font size.
    b. Name of the author(s) should follow the title in new paragraph in normal 9-point font size. Other details of every author's identification such as working organization, contact addresses including telephone, and e-mail should go in the foot notes. The foot notes should be in 8-point font size and marked in Arabic successively.
    c. The first level headings should be all capitalized and bold. The second level headings should be all capitalized and normal. The third level headings should be in sentence case, italicized and normal.

d. In tables, borders should be minimized, and text and numbers should be in 9-point font size.

e. Bibliographic entries in the reference should be in 9-point font size.

7. Number of footnotes should be minimized, and it should not come for citation.

8. Many/big tables and figures in the text should be avoided. Supplementary figures and tables may be placed in the annexure.

9. References should be given in alphabetical order by author's name, and the styles should differentiate the references such as books, journals, newspapers and other unpublished materials. The material not cited in the main text must not come under reference. Private communication, radio listening and TV watch should not appear in the citation as well as in the reference. Some examples of bibliographic entries follow.

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For a magazine article: Pandey, R.R. and Pradhanang, P.M., 1995. Potato wilt and its control measures (Nepali). In: Prabidhi Sangalo, vol. 9(3): 99-102. Lumle Agriculture Research Center, Pokhara. Nepal.

For a year book/report/periodical: UNESCO, 1986. Statistical year book. Paris : UNESCO Press.

National Pay Commission, 1992.A report on the pay structure for civil servants. Kathmandu: Aradhana Press.

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For thesis/dissertation: Pokhrel, D. M., 2005. Citrus marketing system in the mountains of Nepal: a study based on market structure, conduct and performance analyses. PhD dissertation submitted to School of Environment, Resources and Development, Asian Institute of Technology, Thailand.

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11. The Editor-in-Chief and the Editorial Board are not responsible for any damage or loss of submitted manuscript and return of unaccepted manuscripts to the authors whatsoever.

12. The Editor-in-Chief deserves final right to accept or reject a submission.

13. Previous issues of the journal are available at http://www.moad.gov.np.

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INTRA-VARIETAL DIVERSITY IN LANDRACE AND MODERN VARIETY OF RICE AND BUCKWHEAT

Bal Krishna Joshi[1], Suk Bahadur Gurung[2], ParashM. Mahat[3], Bharat Bhandari[4] and Devendra Gauchan[5]

ABSTRACT

The increased intra-varietal diversity has been considered as coping mechanism against unpredictable environmental factors in crop production. Relatively the risk of crop failure is minimum in landraces than in modern variety mainly because of homogenous population in modern variety. The diversity was estimated and compared between landrace and modern variety of rice and common buckwheat in both quantitative and qualitative traits. Three landraces and three modern varieties of rice were used as self-pollinated crop and experiment was conducted in Jumla. Common buckwheat was used as cross pollinated crop in Kabre consisted of nine landraces and one modern variety. These two experiments were unreplicated and variation was measured at population level. Standard deviation, coefficient of variation and Shannon' diversity index were estimated and variation between landraces and modern varieties was tested using F-test. Dendogram was drawn considering all observed traits for both the crops. In case of rice, variation was higher in landraces than in modern varieties for most of the traits. Variation for majority of the traits was also higher in landraces than in modern varieties of common buckwheat. This higher level of intra-varietal diversity in landraces of both crops might be the major phenomenon to have increased capacity to cope with different environmental stresses. The level of variation in both landraces and modern varieties is trait specific, in some traits, landraces showed higher intra-varietal diversity. The higher level of intra-varietal diversity should be considered for resilient production system and favorable policy environment should be created to promote the use of such diversity.

Keywords: Cluster analysis, diversity index, landrace, modern variety, variation

INTRODUCTION

Genetic diversity is the most important factor to develop new variety that suit diverse environments and farmers' requirements. In Nepal, there are 250 released varieties of 50 crops, 373 registered varieties of 38 crops and 36 denotified varieties of 6 crops (Joshi et al., 2017a). The estimated numbers of landraces are 30,000 of 484 cultivated species across the country (Joshi et al., 2017b). Released and registered varieties are developed either selection of landraces or hybridization followed by selection and it is also called modern/improved variety or high yielding variety. Cultivars are the distinct group of genotypes under cultivation and it includes both landrace and improved variety. Variety is developed by breeders whereas landrace is maintained over the years by farmers. Adoption rate of modern varieties of rice obtained from the farm level survey of 30 districts in 2012 is 12% in High Hill, 65% in Mid Hill and 97% in Taraiagro-ecozones (Gauchan, 2017).

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2 Hill Crop Research Program, NARC, Kabre, Dolakha

3 Agriculture Research Station, NARC, Jumla

4 LI-BIRD, Pokhara, Kaski

5 Bioversity International, Khumaltar, Kathmandu, Nepal

In many cases, farmers have reported complete crop failure from the field of modern varieties. Some farmers later therefore, turn to grow landraces in some areas.

Modern varieties are genetically homogenous and are grown other than the places where evolution took place. In contrast, landraces are heterogeneous population and can withstand the unpredictable environmental stresses. The higher intra-varietal diversity in landraces might be the major factor to minimize the risk of crop failures due to different stresses. High level of intra-specific diversity in traditional varieties is being generated and maintained due to multiple environmental stresses and this diversity has increased their capacity to cope with unpredictable stresses (Jarvis et al., 2016). Broad genetic base in a variety is, therefore, considered one of the strategies to cope with the climate changes. Use of diversity can be a risk-minimizing strategy to reduce insect pests and diseases damages (Mulumba, 2012).

Complete crop failure has not been reported in case of landraces by most of the farmers. Fields of landraces and modern varieties can easily be distinguished simply looking on the morphotypes. The population of modern variety looks similar each other, whereas, field of landraces looks diverse. Even though recent seed policy allows registration of the farmers' varieties (landraces), the need of homogenous population is the requirement of the official policy for the release of modern variety in the country (SQCC, 2014). Farmers have managed unpredictable risk factors by continued cultivation of landraces which has high level of intra-landrace genetic diversity. Development of variety with high level of intra-varietal diversity is one of the strategies to cope with the agricultural problems created by climate changes and provide livelihood options of smallholder farmers in marginal environments. Self and cross pollinated crops varieties may have different level of diversity and resilience capacity to cope with climatic stresses. Therefore, this study was conducted to assess the intra-varietal diversity of landrace and modern variety of both self and cross pollinated crops. Rice (*Oryza sativa* L., 2n = 2x = 24, self-pollinated) and common buckwheat (*Fagopyrum esculentum* Moench, 2n = 2x = 16, cross pollinated) were selected and population level diversity in both landrace and modern variety was quantified.

MATERIALS AND METHODS

Self-pollinated crops are more homogenous than cross pollinated. Due to the inbreeding nature of self-pollinated crops, intra varietal variation may be different than that of cross pollinated crops. Therefore, two crops with different mode of pollination, (rice as self-pollinated and common buckwheat as cross pollinated) were selected for this study. Among the 97 modern varieties of rice, 7 are recommended for High Hill (Joshi et al., 2017a). Three common modern varieties were selected and three local landraces were collected from nearby areas of Bijayanagar, Jumla. There is only one modern variety of buckwheat and therefore, only one was selected for this study. Nine landraces which were grown many years in research stations were selected from coordinated variety trial (CVT) of Hill Crop Research Program (HCRP), Dolakha.

Two experiments were conducted, one in Agriculture Research Station (ARS), Jumla and second in Hill Crop Research Program (HCRP), Kabre in 2016 crop seasons. Rice experiment was in Jumla and buckwheat experiment was in Kabre. Three landraces (Jumli Marshi Darema, Jumli Marshi Mehela and Kali Marshi Humla) and three modern varieties (Lekali-1, Lekali-3 and Chandannath-3) of rice were included in the experiment. Rice was seeded at 31 May 2016 in Jumla. One modern variety (Mithe Phaper-1) and nine landraces (Acc#493, KLF-72-22-520, PL15, FCE5283, Acc#2213, Acc#2234, Acc#5670, Acc#6529 and PC-30) of common buckwheat were used in buckwheat experiment. Buckwheat was seeded at 12 Sept 2016 in Kabre. Experiments were established in unreplicated conditions with plot size of 4 $m^2$for rice and 6 m^2 for buckwheat. All standard agronomical practices were followed.

Three agronomical traits, namely panicle length, number of panicle and root length were measured in five individual plants of each rice landrace and modern variety. Four diseases infestation of blast, neck blast, bacterial leaf blight and sheath rot were scored in 50 individual plants of each landraces and modern variety. In case of buckwheat, four quantitative traits (plant height, number of branches, number of flower clusters and number of seed set) and six qualitative traits (flower color, stem size, stem color, seed color, seed shape and disease occurrence) were observed in 30 individual plants of each cultivar. All characters were measured as described in rice and buckwheat descriptors, which are available at Bioversity International website (https://www.bioversityinternational.org/e-library/publications/categories/descriptors/)

Intra-varietal diversity was explained by mean ± standard deviation and coefficient of variation for quantitative traits. Population variance of landrace and modern variety was tested using F-test. Shannon diversity index (H') was estimated for qualitative data and disease score. Considering all observations, cluster analysis was applied to see the relatedness between landraces and modern varieties. MS-Excel and Minitab software were used for data analysis.

RESULTS AND DISCUSSION

SELF-POLLINATED CROP: RICE

Standard deviation (SD) and coefficient of variation (CV) of panicle length, number of panicle and root length of rice cultivars are given in Table 1. The SD of panicle length was the highest in Kali Marshi Humla followed by Jumli Marshi Mehela. Jumli Marshi Darema expressed the highest SD for number of panicle. The variation in root length was found higher in Jumli Marshi Mehela. The CV of root length in Jumli Marshi Mehela was the highest among three traits of six rice cultivars. Within panicle length and number of panicle, the highest CVs were found in Jumli Marshi Mehela and Jumli Marshi Darema. Landraces have higher SD and CV for all traits.

Table 1. Variation in panicle and root length among modern and landraces of rice evaluated in Jumla 2016

Cultivar	Panicle length (cm)			Panicle/ Hill (n)			Root length (cm)		
	Mean	SD	CV, %	Mean	SD	CV, %	Mean	SD	CV, %
Jumli Marshi Darema	114.2	12.6	11.0	11.8	3.8	32.5	8.4	1.1	13.6
Jumli Marshi Mehela	101.2	15.3	15.1	9.8	2.8	28.3	10.8	4.0	36.7
Kali Marshi Humla	113.4	15.4	13.6	8.4	2.1	24.7	11.4	2.1	18.2
Lekali-1	121.8	13.9	11.4	7.4	1.5	20.5	8.4	1.3	16.0
Lekali-3	119.4	14.1	12.5	9.4	1.1	12.1	8.2	2.2	26.4
Chandannath-3	117.2	13.2	11.3	7.4	2.1	28.0	9.6	2.1	21.6

Variance between landrace and modern variety was tested for each of three traits. The variances were significantly different for number of panicle and root length (p=0.05) between landrace and modern variety (Table 2). Landrace had more SD for panicle length however; variation was not significantly different between them. Shannon's diversity index (H') based on the disease infestation score was higher in landrace than that of modern variety for four diseases, bacterial leaf blight, blast, sheath rot and neck blast (Table 3). Cluster analysis had formed four clusters (Figure 1). All three modern varieties (Lekali-1, Lekali-3 and Chandannath-3) made a single cluster and each of three landraces made other separate cluster. Jumli Marshi Mehela was noticed as separate landrace considering these three agronomical traits and four disease infestation score.

Table 2. Variance test between landrace and modern variety of rice

Cultivar type	Panicle length (cm)			Panicle/ hill (n)			Root length (cm)		
	Mean	SD	p-value	Mean	SD	p-value	Mean	SD	p-value
Landrace	109.6	14.8	0.75	10.0	3.1	0.04	10.2	2.8	0.05
Modern variety	119.5	13.5		8.1	1.8		8.7	1.9	

Table 3. Shannon's Diversity Index (H') of diseases for rice cultivar types

Cultivar type	Bacterial leaf blight	Blast	Sheath rot	Neck blast
Landrace	1.36	1.31	1.67	1.01
Modern variety	1.18	1.03	1.55	0

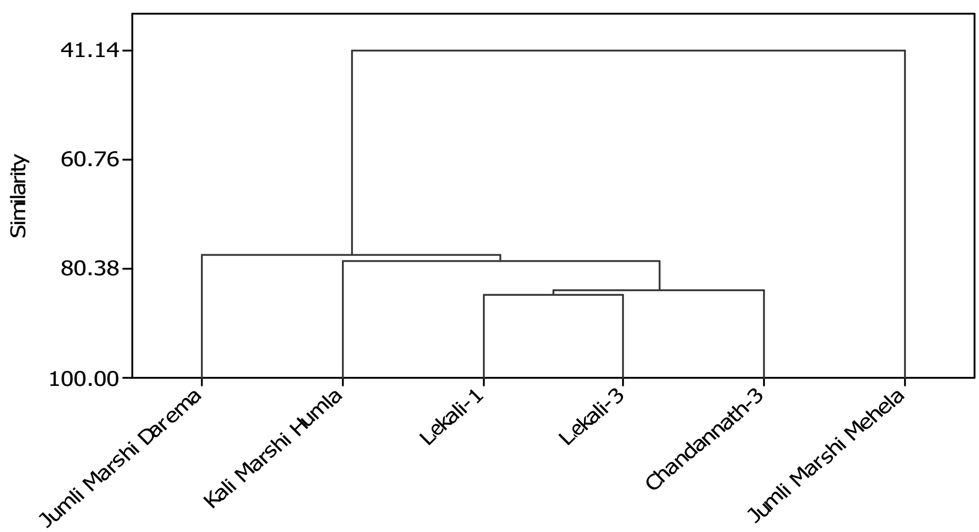

Figure 1.Clustering of landraces and modern varieties of rice based on seven traits

CROSS POLLINATED CROP: COMMON BUCKWHEAT

The highest SD for plant height was observed in landrace, Acc#2234 (Table 4). FCE5283 landrace expressed the highest SD for number of branches and number of flower clusters. The SD for number of seed set was higher in modern variety (Mithe Phaper-1). Among the traits, the highest CV was of number of seed set in landrace PL15. The CV of all four traits was higher in landraces.

Table 4. Variation in agronomical traits among modern and landraces of common buckwheat evaluated in Dolakha, 2016

Cultivar	Plant height (cm)			Branches/plant (n)			Flower clusters/plant (n)			Seed set/ cluster (n)		
	Mean	SD	CV, %	Mean	SD	CV, %	Mean	SD	CV, %	Mean	SD	CV, %
Acc#493	80.80	8.85	10.96	5.40	1.52	28.19	11.90	3.23	27.15	2.03	0.76	37.62
KLF-72-22-520	85.80	10.14	11.82	5.40	1.40	26.01	11.60	4.01	34.53	1.97	0.32	16.26
PL15	80.40	10.12	12.59	5.27	1.53	29.05	11.93	3.69	30.96	1.83	0.79	43.17
FCE5283	79.10	10.03	12.67	5.43	2.03	37.34	10.87	4.21	38.72	2.23	0.68	30.40
Acc#2213	72.03	9.84	13.66	4.97	1.16	23.34	9.87	1.76	17.80	2.23	0.68	30.40
Acc#2234	76.97	10.88	14.13	5.10	1.24	24.34	10.40	3.86	37.16	2.30	0.60	25.91
Acc#5670	74.07	9.14	12.34	5.53	1.94	35.11	9.97	3.98	39.92	2.10	0.55	26.08
Acc#6529	74.97	8.31	11.09	5.20	1.37	26.44	10.73	4.19	39.07	2.17	0.53	24.49
PC-30	75.83	7.28	9.60	5.00	1.82	36.39	8.53	2.98	34.92	2.23	0.57	25.45
Mithe Phaper-1	76.40	10.72	14.03	4.97	1.13	22.73	9.80	2.87	29.28	2.10	0.88	42.13

Among the four agronomical traits, the variation was significantly different between landrace and modern variety of common buckwheat only for number of branches (Table 5). Landrace type had more variation compared to modern variety. Shannon's diversity index of modern variety was higher than landraces for flower color and stem color (Table 6). However, Shannor's diversity index (H') was higher in landrace for stem size, seed color, seed shape and disease occurrence. At 87.44 similarity coefficient, there are eight clusters for ten cultivars of buckwheat (Figure 2). Modern variety, Mithe Phaper-1 made a separate cluster with Acc#2234. Each of six landraces made a separate cluster. KLF-72-22-520 landrace was found different among these ten cultivars of common buckwheat based on the both qualitative and quantitative traits.

Table 5. Variance test between landrace and modern variety of common buckwheat

Cultivar type	Plant height (cm)			Branches/plant (n)			Flower clusters/plant (n)			Seed set/ cluster (n)		
	Mean	SD	p-value	Mean	SD	p-value	Mean	SD	p-value	Mean	SD	p-value
Landrace	80.80	8.85	0.31	5.40	1.52	0.05	11.90	3.23	0.52	2.03	0.76	0.42
Modern variety	76.40	10.72		4.97	1.13		9.80	2.87		2.10	0.88	

Table 6. Shannon's Diversity Index (H') of qualitative traits for common buckwheat cultivar types

Cultivar type	Flower color	Stem size	Stem color	Seed color	Seed shape	Disease
Landrace (KLF-72-22-520)	0.90	1.07	0.95	1.06	0.50	0.25
Modern variety	1.04	1.01	1.04	1.04	0.24	0.33
Landrace (Acc#2213)	0.94	1.06	0.3	1	0.64	0.25

Due to narrow genetic base in modern varieties, there is high risk of cultivating them in the context of climate changes. Farmers have two types of cultivars, one landrace and second are modern variety (high yielding variety). Generally it is perceived that the intra-varietal diversity is higher in landrace as compared to modern variety. We quantified and compared statistically the variation between landrace and modern variety through measuring observation at population level in rice and buckwheat. In both crops, variation was higher in landraces for most of the traits and it was significantly different (p = 0.05). Rice is self-pollinated crop, even though diversity is noticed in landraces. Sample size in case of rice was low in this study, and few numbers of quantitative traits were assessed. If we could study in large sample size in many agro-morphological traits, there might be more reliable structure and results can be related to stress management.

Common buckwheat is cross pollinated crop and normally all types of cultivars retain high level of intra-varietal diversity (Joshi and Baniya, 2006). Landraces relatively possessed higher diversity in most of traits observed. The selected landraces were from Coordinated Varietal Trial (CVT) of HCRP (the research station) where, they have been continuously grown over the year giving selection pressure. CVT generally includes selected promising genotypes, which are homogenous. This selection might have narrowed the diversity in these landraces and scenario might be different if we could compare with landraces without any selection (i.e. directly collecting from the farmers' fields). Even during selection of landraces, there might be less variation in landraces collected from progressive farmers as they keep selecting better plants from the population for next season planting.

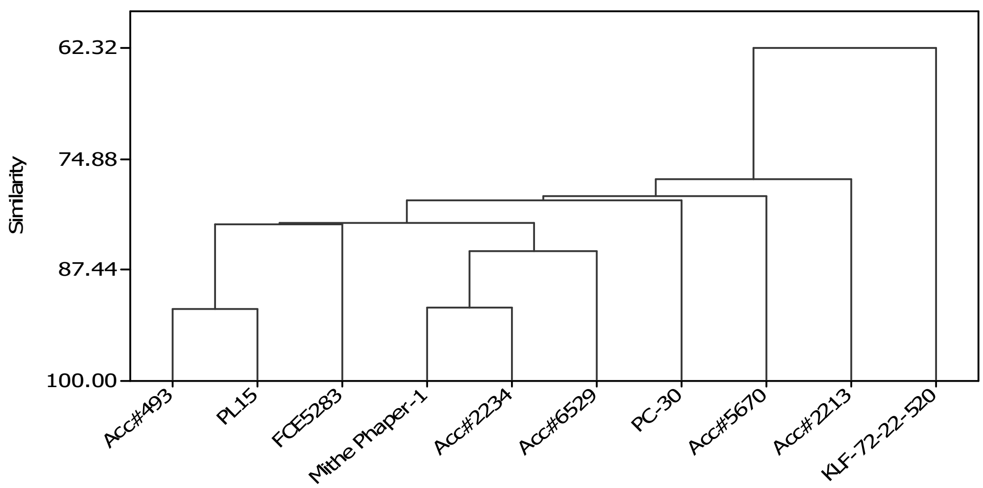

Figure 2. Clustering of landraces and modern varieties of common buckwheat based on ten characters

Higher intra-varietal diversity is reported in landraces of many cultivated crop species. Genetic diversity in wheat landraces was higher than in modern varieties. The degree of associated of landraces with geographical region was relatively stronger than that of modern wheat varieties (Hao et al., 2008). Rice landrace is predominantly inbreeded, however, high level of genetic variation was recorded using micro-satellite markers (Pusadee et al., 2009).The level of gene diversity, even within population level was found same in barley landraces and the representative sample of modern varieties grown in Italy (Bellucci et al., 2013). There are many landraces that are better than modern varieties in terms of production, tolerant to abiotic and biotic stresses and intra-varietal diversity (Genebank, 2016).

Since this trial was conducted on-station with small plot size covering small population size, study is needed to further validate it by studying on-farm taking larger sample size in real farmers' fields. Many of the landraces considered here are imposed to some degree of selection. It would be better to use the landraces either directly collecting from the farmers or taking from the National Genebank to get actual diversity of landraces. It is shown that landraces have higher diversity in both self and cross pollinated crops and separate group have been formed for landraces and modern varieties. Focused study is needed further to quantify the advantages that farmers are taking from such high intra-varietal diversity and to promote the application of the concept at wider scale. Landraces are more resilient, less risk to grow and make agriculture production more sustainable. All these advantages might be because of high intra-varietal diversity, therefore, favorable policy environment should be in practice to release and register the heterogeneous cultivars.

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POPULATION DYNAMICS OF FRUIT FLIES IN SWEET ORANGE (*Citrus sinessis* L.) ORCHARDS IN SINDHULI, NEPAL

Debraj Adhikari[1], Dinesh Babu Tiwari[2] and Samundra Lal Joshi[3]

ABSTRACT

Fruit fly is an important pest of citrus both in relation to production and trade. Fruit fly surveillance was conducted based on protocol endorsed by National Plant Protection Organization (NPPO) Nepal from May 2014 to May 2015. Collection of fruit fly trapped in male lure traps were carried out from the selected sweet orange orchard 64 ha. of Sindhuli district. The trapped fruit flies were collected fortnightly and species were identified. The result shows that the number of fruit flies trapped were higher in methyl eugenol lure than cue lure. The maximum number of fruit flies trapped was found during June, July and August. Bactrocera dorsalis was predominant in Methyl eugenol. Whereas, Bactrocera tau was found major species trapped in cue lure. Besides, other species such as Bactrocera zonata, B. cucurbitae, B. scutelaris and Dacus longicornis were also detected in traps.

Key words: *Bactrocera*, Cue lure, fruit fly, methyl eugenol, population dynamics, sweet orange

INTRODUCTION

Citrus, a commercially grown fruit crop in the middle mountain region of Nepal, is cultivated in 38988 ha (25497 ha productive area) with a production of about 224,357 mt in 2014 (MoAD, 2014). Sweet orange (*Citrus sinensis* L.) Osbeck) is the second important citrus fruit after mandarin (*Citrus reticulata* B.) in the country (Paudyal and Subedi, 2008), and recently citrus fruits, particularly mandarin from Syangja and sweet orange from Sindhuli, were to move to China from Nepal with a bilateral agreement in 2012 (Sharma *et al*., 2015). But fruit flies in citrus as fruit infestants remained hurdles in export (Adhikari, 2013). Fruit flies, *Bactocera cucurbitae* C.*, B. dorsalis, B. zonata, B. tau, B. scutellaris, B. yashimotoi, B. minax, B. caudatus, B. correcta and B. diversus* are predominantly occurring flies in horticultural ecosystem and infesting fruits (Sharma *et al*., 2015). Fruit flies of *Bactrocera* (*Dacus*) spp. remained the cause of mandarin decline typically due to fly initiating fruit droppings in the western hills of Nepal (Budathoki and Pradhanang, 1992). In this context, a survey of the citrus orchards of the hilly districts of Nepal namely Sindhuli and Syangja was conducted to identify orchard maundering fruit flies, their occurrences and seasonal abundance that might pose major threats to sweet orange cultivation in Sindhuli district.

These days, export of citrus fruits from Nepal is facing phytosanitary restrictions due to the fruit fly problem in the orchards. So, the citrus growers are facing problems to export fruits and fetch higher price of their produce. A study by Sharma et al.(2015) revealed that there are ten species of fruit fly species namely *Bactocera cucurbitae C., B.dorsalis, B.zonata, B.tau, B.scutellaris, B.yashimotoi,*

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B. minax, B. caudatus, B. correcta and *B. diversus* in Nepal. The management measures of fruit fly practiced by the farmers were use of para-pheromone (methyl eugenol and cue lure) traps, application of chemical measures and field sanitation of attacked fruits (Jaisawal et al., 1997). Besides, the application of botanical insecticides, exclusion measures (bagging and netting), application of food lures/baits and cultural measures such as soil treatment/tillage, removal of host plants and crop rotation were also the recommended practices to manage fruit fly in Nepal.

Fruit flies are considered as devastating pest in most of the fruits and fruit vegetables (cucurbits and solanaceous). These are polyphagous, having higher rate of fecundity and ability to quickly spread over a wide area that makes them real vexatious pests for fruits and vegetable growers (Gillani et al., 2002). Han et al., (2011) mentioned four to five generations of *Bactrocera dorsalis* per year in Wuhan, Hubei Province, Central China. Chinese citrus fly (*B. minax*) is very serious fruit fly species causing great loss to citrus fruits i.e. sweet orange, hill lemon and mandarin too in the eastern hills of Nepal (NCRP, 2012). The information on fruit fly species abundance in citrus orchard of Sindhuli district was not available yet. This study was undertaken with the view to identify the diversity of fruit flies prevalent in citrus ecosystem in Sindhuli district and to know the distribution pattern of fruit fly population in that location. The work towards compliance after Nepal-China agreement 2012 by National Plant Protection Organization (NPPO) Nepal was presented in Table 1.

Table 1: Work towards compliance in Nepal

Related ISPM	Major Criteria	Procedrure followed
International Standards for Phytosanitary Measures (ISPM) 4 -Requirements for PFA	- Systems to establish freedom - Phytosanitary measures to maintain freedom - Checks to verify freedom has been maintained	- Pest detection survey carried out as a basic step to support Pest Risk Analysis (PRA) and Pest Free Area (PFA) - Pest data recording
ISPM 6 - Guidelines for surveillance	- Guidelines for general and specific survey	- Followed in pest specific survey protocol preparation
ISPM 8 - Determination of Pest status in an area	- Presence of the pest - Absence of the pest - Transience of the pest	- Pest detection survey to support the pest determination
ISPM 10 - Requirements for the establishment of PFPP and PFPS	- Systems to establish pest freedom - Systems to maintain pest freedom - Verification that pest freedom has been attained or maintained - Product identity and phytosanitary security of the consignment	- Work to support Pest Free Place of Production (PFPP) - Orchard selection, registration - Pest detection survey - Pest recording - Pest management activities
ISPM 26 Establishment of Pest Free Area for fruit flies (Tephritidae)	- The characterization of the Fruit Fly - Pest Free Area (FF-PFA) - The establishment and maintenance of the FF-PFA	- Mainly pest monitoring work - Realized very difficult task to these locations - Only Chile has made PFA for FF

ISPM 29 Recognition of Pest free area and Area of Low pest prevalence	- Procedure for PFA recognition	- Preparation for dialogue with trading partner after the agreement

The activities accomplished by NPPO Nepal after Nepal China agreement were:

- Discussion, review, guidelines preparation and field works to support agreement.
- PPD as NPPO has focused on specific survey to detect the concerned pests.
- Pest survey protocols for quarantine pests and survey plans are prepared.
- Orchard selection and registration by District Agriculture Development Office (DADO)
- Field surveys for the particular pests are continued since May 2014.
- Internal Quarantine Directive

MATERIALS AND METHODS

Fruit fly (FF) monitoring based on the fruit fly surveillance protocol to detect the stated quarantine fruit flies in Nepal-China Agreement 2012 was conducted during May 2014 to May 2015 in the citrus orchards of Sindhuli district. FFs male lures originated from para-pheromones, methyl eugenol (ME) and cue-lure (CL) were used with malathion (Malathion 50 EC) to knock-down flies inside the Steiner traps provided by National Plant Protection Organization/Nepal (Plant Protection Directorate, Hariharbhawan, Lalitpur). Sixty-four traps randomly placed in the sweet orange orchards of Ratanchura, Jalkanya, Baseswor and Tinkanya Village Development Committees (VDCs) (Figure 1) Sindhuli district in tree branches at a height of 2 meters from the ground level each at a distance of minimum 5 meters from ME and CL trap and 100 meters from each sets of traps in the orchard. Trapped fruit flies were fortnightly collected, and lures along with Malathion soaked cotton swab were replaced in every fifteen days. Identities of each trapped FFs were made based on their morphological traits on body by means of 20 x pocket lens in laboratory, Ratanchura, Sindhuli. Data of FFs' abundance, distribution and species composition were analyzed by means of Excel data analysis package.

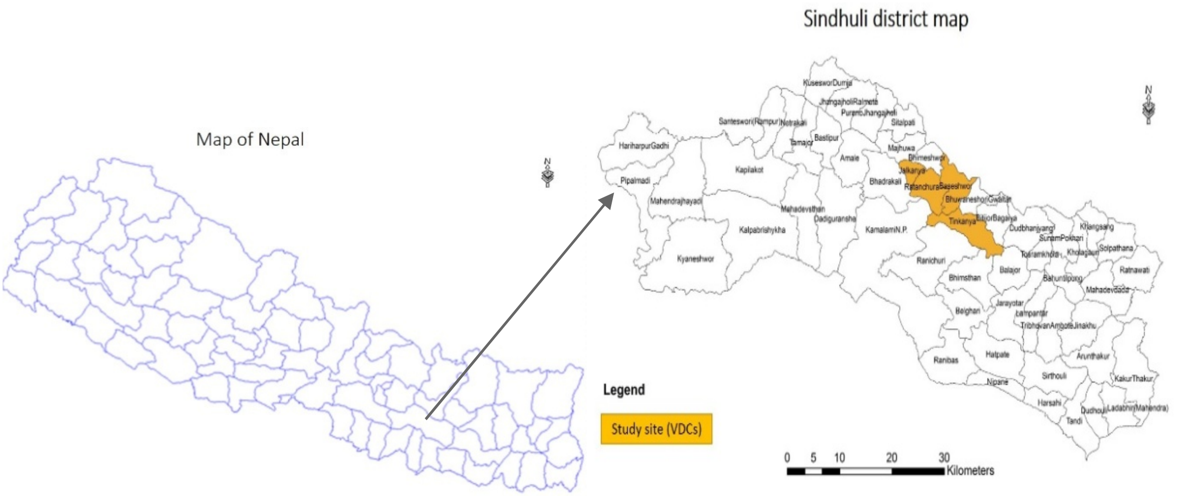

Figure1. Study sites in Sindhuli district

RESULT AND DISCUSSION

Fruit fly is an important pest of horticultural crops. In Nepal, farmers are practicing the integrated measures of management. Though, the yield loss has not been reduced satisfactorily, fruit fly surveillance in Nepal is officially initiated by National Plant Protection Organization after the agreement with China on 2012 to export Nepalese citrus fruits (Sharma et al., 2015).

a. ABUNDANCE OF FRUIT FLY

Fruit flies were observed throughout the year in the orchard. The number of fruit flies trapped in Methyl Eugenol was found higher than the Cue Lure trap. The highest number of fruit fly trapped in Methyl Eugenol was found during 24th July, 2014 i.e. 32415 from 64 traps. Whereas, highest number of fruit fly trapped in Cue Lure was found in the collection of 9th July, 2014 i.e. 2258. As a whole, the largest number of fruit flies trapped in para-pheromone lures were during June, July and August in both traps (Figure 2). This might be due to the weather condition, i.e. higher temperature and humidity during June to August that is favorable for the fruit fly. The greater numbers of fruit flies were trapped from May to August in guava and nectrin in Islamabad, Pakistan (Gillani et al., 2002). Similar result was found by Sarwal et al. (2014) in mango orchard in Faisalabad, Pakistan. The availability of preferred host fruits and the low winter temperature are key factors influencing population fluctuations (Han et al., 2011).

Average number of fruit flies trapped in different lures and standard deviation from May 2014 to May 2015 in sweet orange orchard of Sindhuli, Nepal is presented in Figure 3 which shows that on an average the larger numbers of fruit flies were found in Methyl eugenol i.e. 4689 than Cue lure i.e. 844. Likewise, the standard deviation is higher in Methyl eugenol than Cue lure i.e. 8890 and 679, respectively. There were very low number of fruit fly trapped during winter months might be due to the cold temperatures. Similar result was found by Peng and Hui in 2007.

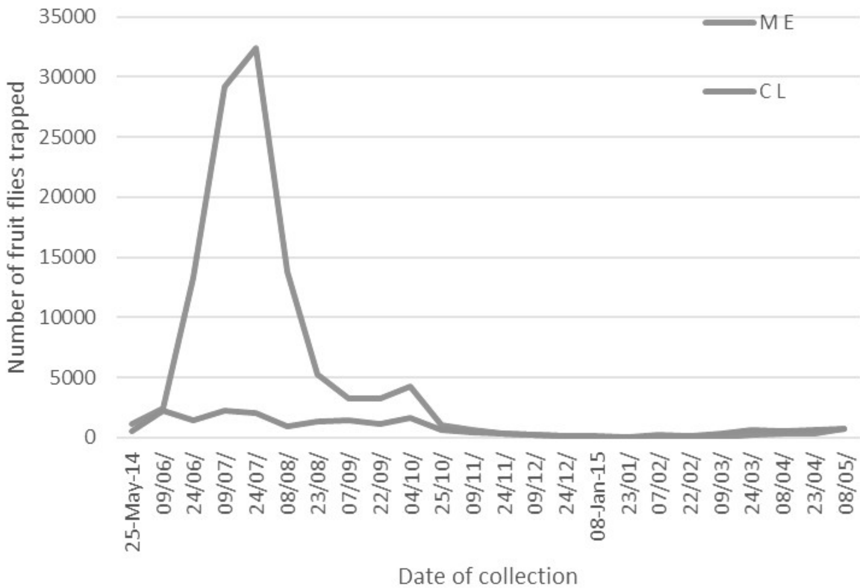

Figure 2. Number of fruit flies trapped in different lures from May 2014 to May 2015 in sweet orange orchard of Sindhuli, Nepal

b. DISTRIBUTION OF FRUIT FLY

Bactrocera dorsalis H.was the most abundant fruit fly species trapped in Methyl Eugenol followed by *Bactrocera zonata, B. tau, B. scutelaris* and *B. cucurbitae*. Whereas, the *Bactrocera tau* was the most abundant fruit fly species trapped in Cue Lure followed by *Bactrocera dorsalis, B. cucurbitae, B. scutelaris, B. zonata* and *Dacus longicornis*. The highest numbers of fruit flies were recorded in Methyl eugenol trap during 24th July, 2014 (Figure 3). Whereas, In Cue Lure trap the fruit fly species *Bactrocera dorsalis* were recorded highest during 9th July, 2014 and the Bactrocera tau during 4th Oct., 2014 (Figure 4).

Among the ten fruit fly species reported from Nepal by Sharma et al. in 2015, five species namely *B. dorsalis, B. zonata, B. cucurbitae, B. tau* and *B. scutelaris* were found trapped and the species *Dacus longicornis* was also reported. Only four fruit flies were diagnosed as *Dacus longicornis* that were trapped in Cue Lure trap on 22nd Feb. i.e. 2 and 1 each on 9th and 24th March, 2015. Methyl eugenol (4-allyl-1,2-dimethoxybenzene -carboxylate) and cue-lure [4-(p-acetoxyphenyl)-2-butanone] are highly attractive male pheromone lures to oriental fruit fly, *Bactrocera dorsalis* (Hendel), and melon fly, *B. cucurbitae* (Coquillett), respectively (Vargas et al., 2000). Population dynamics of the Oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae), were monitored year-round using methyl eugenol-baited traps in 2003 to 2006 in Baoshanba, Yunnan Province, China. The result showed that, the environmental factors such as air temperature, rainfall, sunlight hours, relative humidity and host-plant species were found affecting the population dynamics. The *Bactrocera dorsalis* occurred only during April–November, with one yearly peak in August (Peng and Hui, 2007). The seasonal increase in population size also coincided with the fruiting period of the host plants. The temperature and relative humidity significantly influenced the fruit fly population (Appiah et al., 2009; Peng and Hui, 2007).

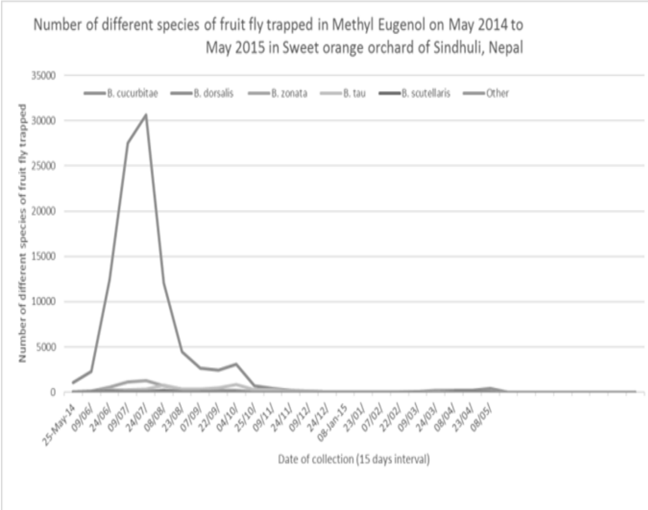

Figure 3. Number of different species of fruit fly trapped in Methyl Eugenol from May 2014 to May 2015 in Sweet orange orchard of Sindhuli, Nepal

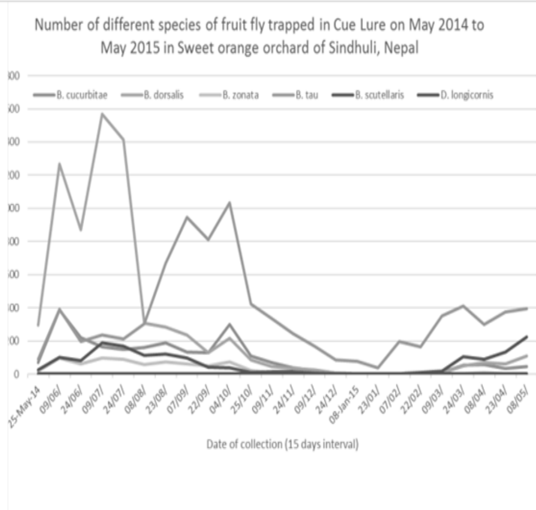

Figure 4. Number of different species of fruit fly trapped in Cue Lure from May 2014 to May 2015 in Sweet orange orchard of Sindhuli, Nepal

c. COMPOSITION OF TRAPPED SPECIES

The composition of fruit fly species trapped in Methyl Eugenol is presented in Figure 5. *Bactrocera dorsalis* were trapped highest i.e. 90.07% followed by *B. zonata, B. tau, B. scutelaris* and *B. cucurbitae* 4.56%, 4.21%, 0.66% and 0.49%, respectively. Similarly, the composition of fruit fly species trapped in Cue Lure is presented in Figure 6. *Bactrocera tau* were trapped highest numbers followed by *B. dorsalis, B. cucurbitae, B. Scutellaris, B. zonata* and *Dacus longicornis* i.e. 35.05%, 11.67%, 7.91%, 3.55% and 0.02%, respectively. This variation in the species of fruit flies attracted and trapped is must be due to the differences in para-pheromone lure and agro-ecological condition of the orchard. Fruit flies are attractive to the specific male lures (para-pheromones). Each lure is specific to a fruit fly group or in some case certain species of fruit fly. Methyl eugenol, cue lure and trimed lure are commonly used to monitor oriental, melon and mediterrean fruit flies, respectively (HAW-FLYPM, 2016). The mixing of fruit fly species in ME and CL might be due to handling of both lures together and placement of traps nearer i.e. +- 5 m. Steiner (1952) reported the attraction of male oriental fruit flies to ME from as far as 800 m.

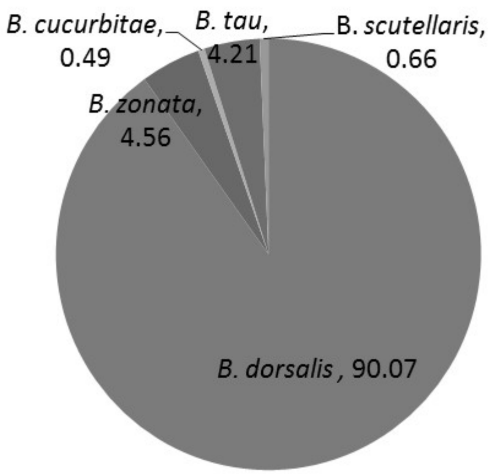

Figure 5. Percentage of fruit fly species trapped in Methyl Eugenol from May 2014 to May 2015 in Sweet orange orchard of Sindhuli, Nepal

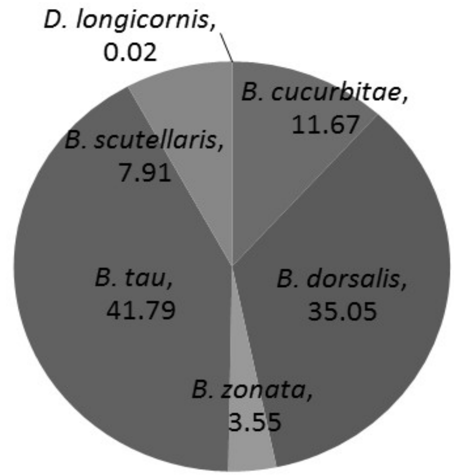

Figure 6. Percentage of fruit fly species trapped in Cue Lure from May 2014 to May 2015 in Sweet orange orchard of Sindhuli, Nepal

CONCLUSION

Fruit fly surveillance in the sweet orange orchard of Sindhuli district, Nepal is important for the study of population dynamics, species diversity and also for the planning of management strategy. It showed that the seasonal variations produce the great influence in fruit fly population. There was less abundance of fruit flies during winter months and highest population during June-August. The result supports the previous findings that the fruit fly population depends upon the environmental factors and host availability. *Bactrocera dorsalis* is the predominant species of fruit fly in sweet orange orchard of Sindhuli Nepal. Though, the damage due to *Bactrocera minax* was observed by the farmers during the harvest of 2015. This emphasizes the need of continuous surveillance also for the other host plants of fruit fly and management measures to minimize fruit loss and for quarantine purpose.

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PREVALENCE OF WHITE GRUBS (SCARABAEIDAE; COLEOPTERA) IN DIFFERENT AGRO-CLIMATIC REGIONS OF NEPAL

Dipak Khanal[1], Manoj Pokhrel[2] and Yubak Dhoj GC[3]

ABSTRACT

White grubs are economically important insect pests in Nepal, however, a strategic management is still lacking. The current study reports on a field collection with the aim to elucidate the dynamics of white grubs in different geographical situations and agro-ecological regions of Nepal. Based on a pest map published by the Minstry of Agricultural Development (MoAD), white grubs occur in six districts representing high-hills (Makawanpur, Kaski, Dadeldhura, Baitadi, Ilam and Terhathum), three districts representing mid-hills (Doti, Tananhu and Parbat) and twodistricts representing Terai (plains, Chitwan and Nawalparasi). Besides differences in sea-level, these districts cover a wide geographical range from the eastern to the western parts of Nepal. Ten white grub infested sites each of the districts Parbat, Kaski, Nawalparasi, Tananhu, Chitwan, Makawampur and three each of Ilam, Terhathum, Dadeldhura, Baitadi and Doti were selected for field sampling. At each selected site, 6 pits of 1m × 1m × 30cm (crop depth) were dug within 100 m^2 area. Longitude, latitude and altitude of each site were recorded using GIS. White grubs at different growth stages were collected and counted. Result shows that the highest number of white grubs was found in Siddeshor-7 and Baitadi (82 larvae), followed by Ashigram-7 and Dadeldhura (54 larvae). There are various spots where no grubs were observed. This study suggests that white grubs are the key pest in uplands of the western part and major pests in uplands of the central region of Nepal. Further studies on the species-specific distribution of the white grubs and on the development of area-wide management strategies are recommended.

Key words: Coleoptera, mapping, sampling, scarabaeidae, white grubs

INTRODUCTION

Insect pests are the major limiting factors to crop production systems, and cause about 12-15% of crop losses worldwide (Upadhyaya, 2003) and 15- 20% in Nepal, respectively (Joshi *et al.*, 1991; Palikhe *et al.*, 2003). Soil insect pests are becoming a major problem to the productivity of different upland crops (Oya, 1996; Potter *et al.*, 1992). Among soil insect pests, white grubs (Coleoptera: Scarabaeidae) are the soil-living and root feeding immature stages of scarab beetles, of which both adult and larval stages may be destructive in nature. The white grub family is the second largest omnipresent family, and exceeds 30,000 species (Mittal, 2000). The larvae of the so-called chafer beetles are commonly known as "white grubs". They are characterized by their C-shaped white colored body with a brown head capsule. The grubs feed on roots of almost all crops, grassland plants and forest trees (Oya, 1995; Fujiie and Yokoyama, 1996: Arita *et al.*, 1993; Potter *et al.*, 1992). Certain white grub larvae have been reported to prefer corn, groundnut, potatoes and

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strawberries, and dislike legumes (Matheson, 1985), sweet clover (Metcalf and Flint, 1975) and lucerne (Keller *et al*., 2000).

All white grubs live in the soil and are phytophagous, feeding upon living plant roots and tubers while ingesting at the same time small quantities of soil and organic matter. For hibernation, they migrate downward to a depth of up to 1.5 meter and remain inactive until the following spring. Usually, the greatest damage occurs after larvae return to upper soil levels to continue feeding after diapause. The same cycle is repeated for another year, until larvae are fully grown at the end of the third spring. Third instar larvae, which causes more damage to host plants than the earlier instars, are present from the end of June until October. Once they stop feeding, fully grown larvae burrow deeper into the soil and form a cell in compact soil layers, usually at a depth of 20-30 cm. This takes place from August onwards and is completed by all individuals in November. Within this oval, earthen cells pupation takes place in February or March under field conditions, but may occur earlier in the laboratory.

The extent of damage caused by white grubs depends mainly on the species involved, the numbers of individuals present and the host crops. The damage caused may be severe. Previous studies have estimated yield reduction of 40-80% (Prasad and Thakur, 1959; Raodeo, 1974). A recent study recorded yield reductions of 12-60% (Pokhrel, 2004). This study is a first attempt to elucidate the distribution pattern of white grubs and their densities in the three agro-climatic regions of Nepal.

MATERIALS AND METHODS

FIELD SAMPLING OF WHITE GRUBS

The field survey was carried out from October, 2009, to November, 2010 along the whole longitudinal range of Nepal. Based on pest map published by the Minstry of Agricultural Development (MoAD), white grubs occur in six districts representing high-hills (Makawanpur, Kaski, Dadeldhura, Baitadi, Ilam and Terhathum), three districts representing mid-hills (Doti, Tananhu and Parbat) and two district representing plains (Chitwan and Nawalparasi). Ten white grub infested sites each in the districts Parbat, Kaski, Nawalparasi, Tananhu, Chitwan, Makawampur and three each of Ilam, Terhathum, Dadeldhura, Baitadi and Doti were selected for field sampling. The infested areas were identified based on the information provided by the District Agriculture Development Offices (DADOs). At each selected white grub site, 6 pits of 1 m × 1 m × 30 cm (crop depth) were dug within a 100 m^2 area. Longitude, latitude and altitude were recorded using GPS (Garmin). White grubs at different growth stage were collected, counted and brought to the laboratory of the Entomology Division, Nepal Agricultural Research Council (NARC), at Lalitpur for further study. During field sampling, the cropping pattern of the field site was also recorded. Altogether survey was carried out in 450 plots of 75 infested sites in 11 districts.

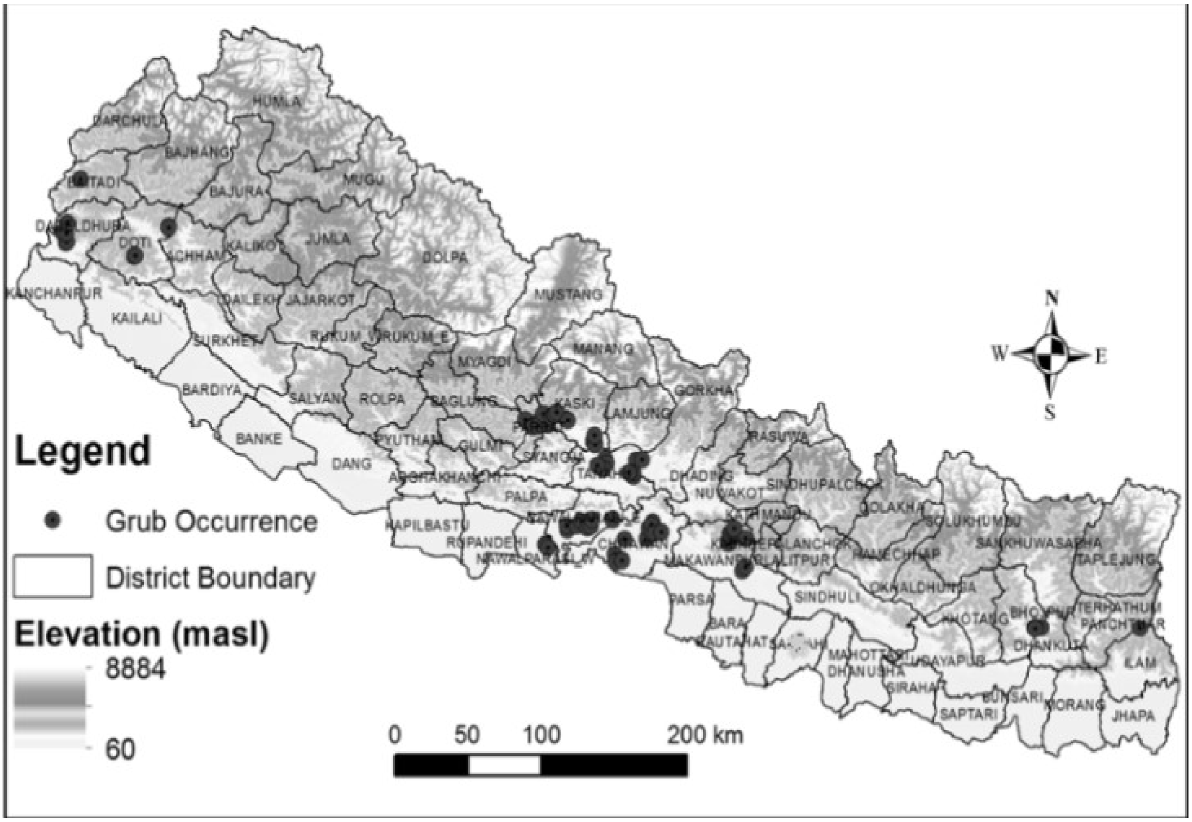

Figure 1. Map of Nepal showing infested areas included into the survey

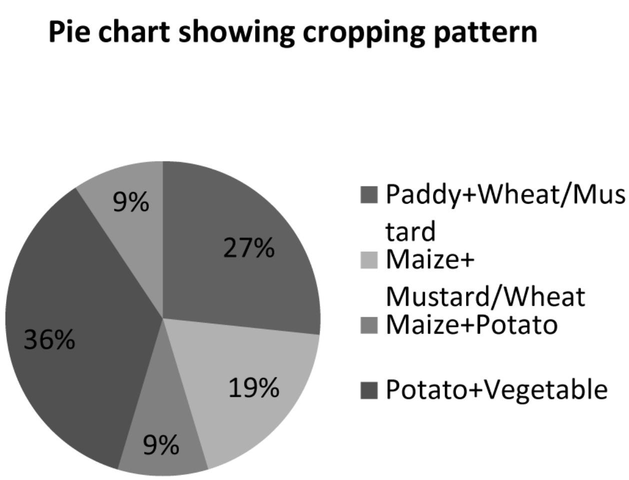

Figure 2. Pie chart showing different cropping patterns present at the sampling sites

Table 1: Prevalence of white grubs (larvae) in different geography and agro-climatic regions of Nepal

Districts	White grubs prone areas	Altitude (masl)	No. of larva per site Sites						CP	Districts	White grubs prone areas	Altitude (masl)	No. of larva per site Sites						CP
			I	II	III	IV	V	VI					I	II	III	IV	V	VI	
Parbat	Pang-3	1068	4	3	3	0	1	2	1	Tanahu	Bandpur-1	515	2	1	3	1	2	2	3
Parbat	Chuwa-4	914	7	2	3	3	4	4	1	Tanahu	Purkot-7	482	1	2	2	1	2	1	3
Parbat	Tilhar-8	1138	0	3	2	0	4	3	1	Tanahu	Keshobtar-2	521	3	2	1	2	2	3	3
Parbat	Chuwa-5	890	5	0	1	0	2	2	1	Chitwan	Bachauli-3	172	1	0	1	0	1	2	4
Parbat	Chuwa-4	902	3	0	5	3	8	7	1	Chitwan	Gardi-7	198	2	1	2	0	1	2	4
Parbat	Chuwa-4	886	2	4	0	8	2	2	1	Chitwan	Bagauda-4	187	1	0	2	1	1	0	4
Parbat	Katuwachaupari-2	944	3	4	0	2	0	2	2	Chitwan	Kalayanpur-7	192	1	2	1	0	0	1	4
Parbat	Kautwachaupari-2	881	4	2	3	2	5	2	2	Chitwan	Patiyani-2	146	2	2	1	1	1	3	4
Parbat	Pakuwa- 2	1175	12	7	0	3	6	4	2	Chitwan	Ratnagar-13	188	0	1	2	0	1	1	4
Parbat	Tilhar-9	989	1	6	2	3	0	3	2	Chitwan	Jutpani-4	223	1	2	1	1	2	2	4
Kaski	Bhadauri Tamagi-1	1765	14	11	13	0	9	11	3	Chitwan	Pithuwa-8	208	3	2	2	3	2	2	4
Kaski	Bhadauri Tamagi-1	1741	21	10	7	5	11	1	3	Chitwan	Chainpur-2	184	2	1	2	1	4	0	4
Kaski	Dhikurpokhari-8	1708	7	13	2	3	21	2	3	Chitwan	Birendranagar-7	202	2	3	1	2	1	1	4
Kaski	Dhirkur pokhari-7	1565	13	12	10	2	0	13	3	Makawanpur	Daman-7	2452	14	13	5	14	0	4	5
Kaski	Kaskikot-7	1517	11	14	0	4	12	9	2	Makawanpur	Namatar-1	2213	13	4	0	3	9	3	5
Kaski	Rupakot-8	890	2	3	1	4	2	1	2	Makawanpur	Namatar-3	2116	4	16	14	0	3	13	5
Kaski	Rupakot-8	910	9	0	7	2	4	5	2	Makawanpur	Namatar-3	1798	0	14	7	3	5	7	3
Kaski	Deurali-2	790	6	1	4	4	2	3	2	Makawanpur	Daman-7	2036	14	0	0	14	6	17	5
Kaski	Lekhnath-11	840	1	7	1	2	2	5	2	Makawanpur	Daman-5	1875	0	13	6	15	4	2	5

Kaski	Sarankot-5	1508	21	11	9	15	2	4	2	Makawanpur	Palung-1	1749	4	9	7	3	14	13	2
Nawalparasi	Makar-9	112	1	3	1	4	0	1	4	Makawanpur	Bajrabarahi-1	1775	13	0	9	7	14	0	2
Nawalparasi	Daunne Devi-2	107	2	4	0	0	2	3	4	Makawanpur	Bajrabarahi-6	1901	24	0	3	0	9	9	2
Nawalparasi	Naya Belani-6	156	1	3	2	1	2	3	4	Makawanpur	Kulekhani-8	1530	9	7	7	4	0	14	2
Nawalparasi	Rakachuli_3	245	5	1	4	3	2	0	4	Dadeldhura	Ashiram - 7	1926	16	17	54	18	21	19	2
Nawalparasi	Tamsaria-2	183	3	2	0	0	4	3	4	Dadeldhura	Ashiram - 8	1955	17	35	16	15	44	14	2
Nawalparasi	Deurali-3	219	1	1	4	3	0	1	4	Dadeldhura	Samaiji-7	1575	10	25	11	4	17	18	2
Nawalparasi	Aghauli-9	216	2	0	0	3	3	1	4	Baitadi	Sideshor-7	2199	47	82	28	9	35	20	2
Nawalparasi	Sibhamandir- 4	216	4	1	3	4	0	1	4	Baitadi	Sideshor-8	2193	11	43	24	37	14	9	2
Nawalparasi	Dawadi-7	259	3	0	1	0	2	1	4	Baitadi	Dehimandu-1	2180	17	7	22	15	35	37	2
Nawalparasi	Amarapuri-5	174	0	1	1	3	0	3	4	Doti	Kadamandu-2	1863	18	11	35	25	4	19	2
Tanahu	Ghansi Kuwa-1	484	2	1	5	2	0	1	3	Doti	Ghanteshor-2	1877	19	17	11	19	17	27	2
Tanahu	Vanu-1	740	9	3	7	2	3	0	3	Doti	Ghanteshor-2	1870	19	18	9	31	9	16	2
Tanahu	Syamgha-9	456	1	2	2	1	1	3	3	Ilam	Maipokhari-6	2010	17	15	14	4	11	13	2
Tanahu	Manapan-8	390	1	2	2	1	2	1	3	Ilam	Maipokhari-5	2047	1	14	15	7	7	15	5
Tanahu	Jamune-4	557	1	2	2	4	2	2	3	Ilam	Maipokhari-4	2046	3	18	24	31	16	15	5
Tanahu	Chang-5	584	2	2	1	2	1	3	3	Terhathum	Chitre-6	2351	13	9	9	6	21	10	2
Tanahu	Bandipur-1	939	7	1	0	9	3	3	3	Terhathum	Chitre-5	2454	11	18	17	15	14	34	2
										Terhathum	Chitre-4	2354	5	23	15	15	26	13	2

CP=Cropping pattern; 1=Maize+potato, 2=Potato vegetables, 3=Maize+Mustard/Wheat, 4=Paddy+Wheat/Mustard; 5=Potato+fallow, masl=Meters above sea level

RESULTS AND DISCUSSION

Results show that 36% of the areas included the survey practice of a potato and vegetable based cropping pattern which is followed by paddy and wheat/mustard (27%), maize and mustard/wheat (19%), potato and fallow (9%) or maize and potato (9%) (Figure 2). The highest numbers of white grubs were found in Siddeshor-7 and Baitadi (82 larvae), followed by Ashigram-7 and Dadeldhura (54 larvae) both exhibiting the same cropping pattern, i. e. potato and vegetables. There are various places where no grubs were observed. Results show that the numbers of white grubs increase with increasing sea levels (Table 1). Mid-hill and upper-midhill sites are prone to higher pest population levels and therefore are at risk for severe yield losses. (GC, 2006) also found higher numbers of grubs in hilly areas compared to plain areas. Paddy based cropping patterns seem to be less prone to white grub attack than maize and potato based cropping patterns. This may, however, be an effect of the soil conditions rather than an effect of the crops themselves, since white grubs prefer the loose/loamy soil of maize and potato fields over compact soils in paddy fields. The finding that grub numbers were higher in uplands (Bari) than in plains might be due to the effect of stagnant water during rice cultivation in the latter. Water may cause suffocation and create an unfavorable place for white grub development. Similar results were reported by Khanal *et al*. (2012) who also found higher numbers of white grub (especially chaffer beetles) in potato based farming system rather than paddy based cropping systems.

CONCLUSION

Soil insect pests are becoming a major problem to the productivity of different crops. Among soil insect pests, white grubs (Coleoptera: Scarabaeidae) are the soil-living and root feeding immature stages of scarab beetles, of which both adult and larval stages may be destructive in nature. This study suggests that white grubs are the key pest in uplands of the western part and major pests in uplands of the central region of Nepal.

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IMPACTS OF CLIMATE CHANGE ON ANIMAL AGRICULTURE AND POSSIBLE ADAPTATION MEASURES

Doj Raj Khanal, PhD[1]

ABSTRACT

Most of the developing countries in Asia and Africa with rapidly growing human population are confronted mainly with the problem of food insecurity. Recently, climate change has been a subject of prime concern throughout the planet due to its overall impacts on food security and sustainable livelihoods. Many animal species have become vulnerable to diseases due to global warming which directly or indirectly is related to productivity, conservation of biodiversity and ultimately to food security. Rise in the average temperature is attributed for profound effect not only on the life cycle of parasites but also on the shifting location of the migratory birds carrying influenza viruses. This paper discusses the temperature profile recorded in one agricultural research station of the country for the last one decade indicating the trend of global warming. Further, discussion is also made on how progressively tick population in domestic animals in certain locality is being substituted. Finally, attempt will also be made on discussing how animal industries are contributing to the rise in production of greenhouse gases contributing to climate change besides enlisting possible adaptation measures.

Key words: Adaptation plan, climate change, food security, vulnerability

INTRODUCTION

In the recent times, impacts of climate change have been visible in most part of the world with rise in temperature, unpredicted weather patterns, rise in sea levels and extremes of climatic events. Many of these events have favored for the emergence of new human and animal diseases, increased the incidence of insect vectors and plant pests which ultimately pose threat for the very existence of biodiversity and food security. Any mitigation and adaptation measures taken locally in isolation cannot slow down the pace of climate change but with united actions at regional and global level will help to reduce the speed of climate change and thereby helping to prevent further damage to the planet. Climate change is not only the rise of temperature but also includes trends towards strong storm systems, increased frequency of heavy precipitation events and extended dry periods. These changes have implications for food production, food security and food safety. Unpredictable rains, snow falls and dry spells have immediate impact on crop growth and productivity which affect the chain of livestock feeds and forages.

It is quite obvious that global livestock trade and movement has been a great contributor to the spread of animal diseases like FMD than climatic factors. However, a warmer and wetter world with more extreme climatic events makes animals more vulnerable to diseases. Animal diseases affect livestock enterprises in three major ways which will influence livelihoods of poor people: by reducing the productivity of livestock, increasing vulnerability of poor people and constraining market access by smallholder farmers. In South East Asia, helminths cause 25% reduction in growth

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rates in sheep while the reduction in growth rate among goats ranges from 23% to 63%. About 25% households in western Kenya fell into poverty due to livestock diseases (De Leo, 2009). In Nepal, infectious animal diseases account for annual losses of about 230 million US dollars (Shrestha *et al.*, 2009).

Intergovernmental Panel on Climate Change (IPCC, 2007) reported that 0.76°C increase in the world's average temperature in the last century and is expecting temperature to rise by 2°C by 2050 which ultimately leads to rising sea levels, the disappearance of glaciers, and to drastic change in rainfall patterns, affecting the production potential of rural areas (Taufur *et al.*, 2008). Extreme weather is also associated with increased disease risk. Droughts lead to poor hygiene and malnutrition while floods result in contamination of drinking water. Changes in temperature, rainfalls as wells as an increase in extreme weather events are likely to change food production and food distribution systems or to change the purchasing power of, for example, flood victims.

SCENARIO OF CLIMATE CHANGE IN NEPAL

Climate change related research works in animal sectors are yet to start in Nepal. Prolonged political transition, lack of scientific environment and lack of motivation among researchers might have issues in effective implementation for dealing with climate change. There are limited researches carried out in this field and adequate attention is needed on detailed analysis of the existing meteorological data in relation to the incidence of diseases in animals and humans. Both entities have been presented in isolation and especially, many speculative theories have been put forward for the emergence of parasites and diseases due to global warming. Three newer animal diseases having severe socioeconomic impact at global scale namely, highly pathogenic avian influenza (HPAI, H5N1), swine flu (H1N1) and bluetongue that were never reported before have been recorded in the recent months. Likewise, classical swine fever (CSF) has also been established since last decade. Many unrecognized and unreported diseases in animals and humans including recent outbreaks of Dengue with a death toll of more than 25 human lives in Chitwan and adjoining areas are prevalent despite of their long existence in both urban and rural areas of Nepal.

In one retrospective analysis of data, the temperature profile recorded during January, the coldest month of the year for last nine years beginning from 2001 to 2009 at Agricultural Research Station, Pakhribas indicated that (Fig. 1) the average annual temperature has increased by around 1° C in Year 2009 compared to the base year 2001. Similar trend was reported (Khanal *et al*. 2010) for both combined averages of maximum and minimum temperatures for the same period.

Nepal got first outbreak of HPAI in Karkarvitta town of Jhapa district in January 16, 2009 and second outbreak in Gharipatan area of Pokhara Municipality during January 26, 2010 (Nirmal *et al*, 2010). It is presumed that the migratory tract of wild birds has recently been shifted from southern parts of the Asian countries to more northern side of the continent due to rise in average temperature. With global warming, these carrier birds do not have to travel far south to escape the chill winter and instead can find comfortable climate in Nepal and Tibet during the coldest months of January-February. Recent outbreaks of HPAI in Nepal and Tibet are thought to be linked with shifting flight tract of migratory birds.

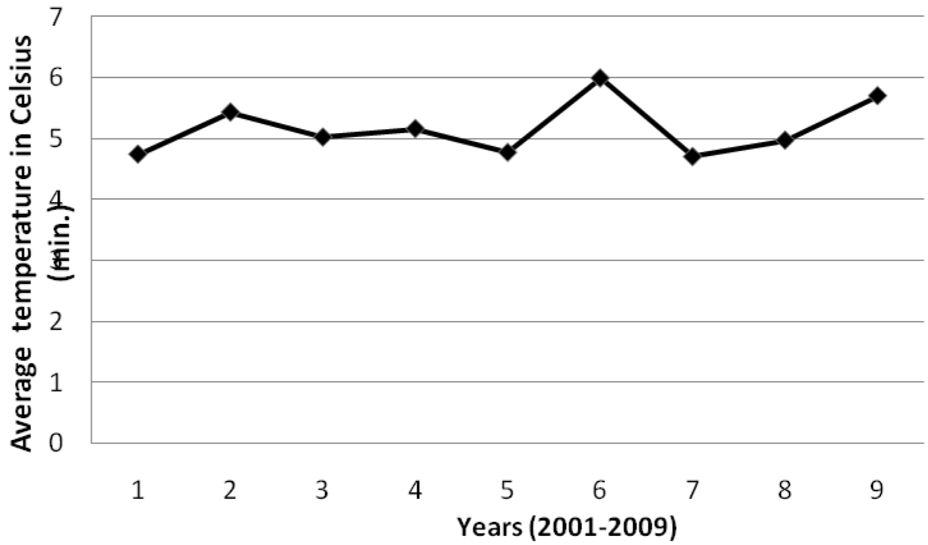

Figure 1. Trend of average minimum temperatures recorded during the month of January at ARS, Pakhribas

With the change in ecological, agronomical and management practice, the microclimate and ecological niche of livestock ticks are undergoing changes leading to disturbances in tick population. A short field investigation carried out by Shrestha *et al*. (2011) in Lele area of Lalitpur found that *Ixodid/Rhicicephalus* (multi host) ticks have been gradually substituted by *Boophilus microplus* (one host) speciesin cattle and goats over the years. It is thought that warmer temperature favouring for the dominance of *Boophilus* species over *Ixodid/Rhipicephalus* may be the reason for reporting of more blood protozoan diseases in Terai and hilly regions of the country.

GLOBAL SCENARIO OF IMPACTS OF CLIMATE CHANGE ON ANIMAL DISEASES

The animal agriculture is responsible for 18%, or nearly one-fifth, of human-induced greenhouse gas (GHG) emissions (FAO, 2006). Climate-changing gases are released into the atmosphere in nearly every step of meat, egg, and dairy production, disrupting weather, temperature, and ecosystem health. Combined effect of increased global trade and global warming on environment is likely to impact on the evolution of new pathogens and hence diseases in animals (Dufour *et al*., 2008). Vector borne diseases do not have boundaries. HPAI H5N1 outbreaks in SE Asian countries in 2005/2006 caused the death of 140 million domestic birds with total economic losses estimated to amount to US$10 billion (FAO/OIE, 2005). Northward shifts in distributions of wild birds have been reported in many species and have been attributed to climate change. Although there is little knowledge on the direct influence of environmental factors such as climate on avian influenza (AI) epidemiology but indirect effects of climate change on agro-ecosystems associating duck and crop production, and of changes in the distribution of domestic–wild waterfowl contact points are anticipated to influence HPAI transmission. Changes in the distribution of rice cultivation resulting from climate changes, such as caused by more frequent droughts or floods, indirectly change the distribution and abundance of the millions of ducks raised in association with these crops and may have a critical impact on the distribution of HPAI persistence risk. By changing the distribution, composition and abundance of wild duck populations, climate change indirectly modifies the interface between domestic and wild waterfowl and with it the potential AI virus flow between aquatic and terrestrial poultry (Gilbert *et al*., 2008).

Heat stress can have a direct and detrimental effect on health, growth and reproduction. Changes in the nutritional environment (e.g. the availability of livestock feeds, and the quantity and quality of livestock pastures and forage crops) can have an indirect effect. These effects are expected to be most dramatic in temperate regions due to less availability of quality feedstuffs. Climate change may affect zoonoses in a number of ways. It may increase i) the transmission cycle of many vectors and ii) the range and prevalence of vectors and animal reservoirs. In some regions, it may result in the establishment of new diseases. Consequences of climate change such as changes in feeding practices, changes in the ecological situation in which animals are reared and increased irrigation may exasperate these effects.

Extremes of climatic events like exposure to intense cold, droughts, excessive humidity or heat may predispose cattle to complex bacterial syndromes such as mastitis. Examples of diseases influenced by climate change include Rift Valley Fever, Bluetongue, as well as tick-borne diseases. Animal health may be affected by climate change in four ways: heat-related diseases and stress, extreme weather events, adaptation of animal production systems to new environments, and emergence or re-emergence of infectious diseases, especially vector-borne diseases critically dependent on environmental and climatic conditions (Forman *et al*., 2008). Many diseases are transmitted by vectors such as ticks, mosquitoes and flies, the developmental stages of which are often heavily dependent on temperature and humidity. Sheep, goats, cattle and horses are also vulnerable to an extensive range of nematode infections, most of which have developmental stages that are influenced by climatic conditions.

HOW TO MITIGATE GLOBAL WARMING AND ADAPT PLAN FOR FOOD SECURITY

The following plan of action will be the component of a successful mitigation and national adaptation plan which will directly or indirectly help in achieving food security in the long run:

- Creation of hardy varieties of animal and agricultural crops resistant to drought, floods and pests. This is a huge task by itself for a country like Nepal and needs a robust agricultural research institution with heavy investment in research and development.
- Risk management including stock-piling of drugs and veterinary vaccines; insuring animals and providing micro-credit to the needy farmers. Contingency plans are very important in disaster preparedness. Creation of youth volunteer bodies like Nepal Agricultural Corps and Nepal Veterinary Corps trained to help out in the case of disease outbreaks, such as avian influenza or natural disasters like floods, earthquakes as a means of efficient preparedness plan for natural disaster risk management.
- Improved veterinary and extension services, fodder and seed banks, provision of water points and shades are all required for a good adaptation plan.
- Mimicking Mother Nature by sprinkling water on cattle and buffaloes during heat stress for providing comfort and thereby enhancing productivity.

- Ruminant livestock's feeding regime needs to be readjusted to minimize enteric methane emissions (potent source of greenhouse gases) by gradual replacement of concentrate-based feeds with nitrate-based forages and greens as suggested by Leng (2009). The way cows are fed affects the quality of manure and the quality of manure affects the quality of the soil. The quality and fertility of the soil affects the quality of the pasture and fodder crops and hence the feed, in turn affects the health of the animals and the quality and quantity of the products. For example, reducing the amount of protein and increasing the amount of roughage in the feed, the quality of manure becomes much better than the slurry produced by conventional methods. Reduction of methane emissions from enteric fermentation can be brought by animal productivity gains through improved breeds, animal health and nutrition.
- Burning practices of crop lands and home gardens irrespective of their sizes in the name of rejuvenating farming land should be stopped once for all as this practice destroys all beneficial soil microbes and burning crop residue accounts nearly 14% of greenhouse gas emission. Documentary on composting versus burning of crop land be very useful to convince farmers and ordinary people with cost benefit analysis for a specified period of time.
- As contrary to agriculture mechanization, animal power for traction is to be encouraged over fossil fuel-based tractor for ploughing lands and carriage of farm inputs with some rewards or subsidies from the government after zoning the agricultural lands. Agricultural mechanization using electric or solar power can be promoted in flat Terai whereas environment friendly and more sustainable animal power can be advocated in the hills and mountains. Use of animal power has two more advantages over fossil fuel-based tractor: animal power decreases dependency on fossil fuel-based traction thereby reduces the environmental emission, and more importantly, animal manure will help in enhancing soil fertility.
- Rotational grazing on fallow lands or pasture lands is practiced to maximize the yield of biomass (cost benefit analysis).
- Plantation of bio-diesel plants like *Jatropha* in non-agricultural waste lands should be encouraged instead of promoting corn-based bio-ethanol production. Corn based bio-ethanol production has already been attributed for the environmental degradation through the leaching effect of chemical fertilizers and pesticides massively applied in the corn fields for higher yields besides causing scarcity of corns for animal feeding.
- Planting of barrier hedges along contours to reduce soil erosion and provide fuel wood. Hedge row plantation of fodder trees and bushes would also help to improve fodder supply.
- Roasting of the corn and other cereal crops exposed to high moisture or flooding to minimize the mould activity and mycotoxin development.
- Roles of mass communication in creating awareness, weather forecast and early warning for making stakeholders follow the accepted farming practices are very high. FM radios, TV broadcasts, video documentaries, environmental journalists' forum and brochures are very helpful in providing climate information and educating the farmers.
- Change in the land use such as agro-forestry and conversion of marginal land to forests.

CONCLUSION

The emergence of new animal diseases and pests has been implicated for climate change which can ultimately result in changes in species composition, threaten global food security and ecosystem as a whole. It is wise for Nepal along with all other global and regional partners to join hands in a concerted manner for adapting suitable mitigation measures and initiate ground-breaking researches that help to slow down the speed of global warming, adopt climate change circumstances and save the planet.

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DEVELOPMENT OF OVERALL AGRICULTURE SECTOR AND MAJOR SUBSECTORS IN NEPAL

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ABSTRACT

Some subsectors of agriculture in Nepal have shown noticeable progress in recent years. The aim of this study was to evaluate the progress of overall agriculture by Agriculture Gross Domestic Product (AGDP) in general and yield increment of major subsectors in particular. A simple regression model was applied in the first stage and further analysis was done using multiple regression models. Five explanatory variables, namely time, fertilizer, irrigation, government expenditure, and rainfall were used. A result of mixed effect was observed in case of rice, maize, wheat, vegetables and potato. The overall agriculture growth (measured in terms of AGDP) showed a positive influence of government expenditure and a negative influence of rainfall. The most important finding of this study is that government expenditure in agriculture sector could produce a very attractive return, i.e. an investment of NRs. 1 million in agriculture generates about NRs. 30.34 million value in the economy. Therefore, government should focus on investment in agriculture to harvest unused potential in agriculture.

Keywords: Agriculture sector, government expenditure, regression model, yield growth

INTRODUCTION

Development of agriculture sector has been considered one of the most efficient means for poverty reduction in the least developed and developing economies. The growth in agriculture sector is taken as an engine of overall economic growth that links the poor people with the benefits of the growth (Timmer, 2005). Research led technological change in agriculture has shown a very good impact in poverty reduction at a lower cost in Africa and Asia (Thirtle et al., 2003). Therefore, governments, donor communities, and international development partners emphasize investment in agriculture as a tool for poverty reduction in the least developed economies. Additionally, growth of this sector is taken as a helpful tool for food and nutritional security in the country as it plays a crucial role in food supply.

Agriculture is the main stay of Nepalese economy that contributes about one-third of gross domestic product (GDP) and about two-third of total employment in the country (Economic Survey, 2015-16). Moreover, agriculture is the main source of food supply for domestic consumption in Nepal. Also, it is the second biggest export sector next to industry in the country (TEPC, 2015). Thus, progress and stagnation of agriculture growth play a major role in Nepal's overall economic growth.

The Government of Nepal (GoN) has been given high priority in the majority of its development plans (NPC, 2013-2073). The GoN has been implementing regular programs, special programs, and many projects for agriculture development for many years. The twenty year Agriculture Perspective Plan (APP) started in 1995/96 has concluded recently. Among four outputs envisaged in the APP,

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the target of expansion of the rural road network was achieved satisfactorily. As a result, the accessibility for farmers has considerably expanded. Likewise, irrigated land has increased considerably from 39.6% to 54% in the same period (ADS, 2015).

The growth of agriculture sector was slow ranging from 1-5% with an average slightly more than 3% in last 16 years from 1997 to 2012 (ADS, 2015). Each year the growth was seen highly volatile. On the other hand, some sub-sectors like crops, poultry, fishery, vegetables, potato, meat and dairy showed noticeable progress in terms of production or/and productivity. This improvement showed positive sign in several indicators such as productivity of agricultural labor rose from $466 to $700/labor, productivity of agricultural land increased from $1,118 to $1,700/hectare, national poverty level reduced from 42% to 25%, and malnutrition of children less than 5 years declined from 60% to 42% from 1995/96 to 2010/11 (ADS, 2015).

However, when compared to immediate neighbour, agriculture in Nepal showed slow growth in the number of indicators, for example, labor productivity, trade and competitiveness, value addition, poverty, infrastructure, and mechanization, Table1 (ADS, 2015). Moreover, when compared the GDP and agriculture gross domestic product (AGDP) growth rate during 1995 to 2010, Nepal is the lowest growth achiever among its neibouring countries. Thus, it is necessary to evaluate the progress of the overall agriculture sector and its sub-sectors in Nepal since only a few studies are available in connection to this issue.

Table1. Performance Indicator of Nepal and Neighboring Countries

Country	Average GDP% over 1995-2010	Average Agricultural GDP% over 1995-2010	GDP/cap ($) in 2010	Arable land/capita (ha) in 2008	Cereal yield (kg per ha) in 2010	Ag GDP/arable land ($/ha) in 2008
Bangladesh	5.6	3.6	673	0.054	3890	1845
China	9.9	4.1	4393	0.082	5460	4467
India	7.2	2.8	1477	0.139	2471	1277
Pakistan	4.2	3.7	1007	0.122	2803	1586
Nepal	4.1	3.0	524	0.082	2374	1665

Source: ADS, 2015

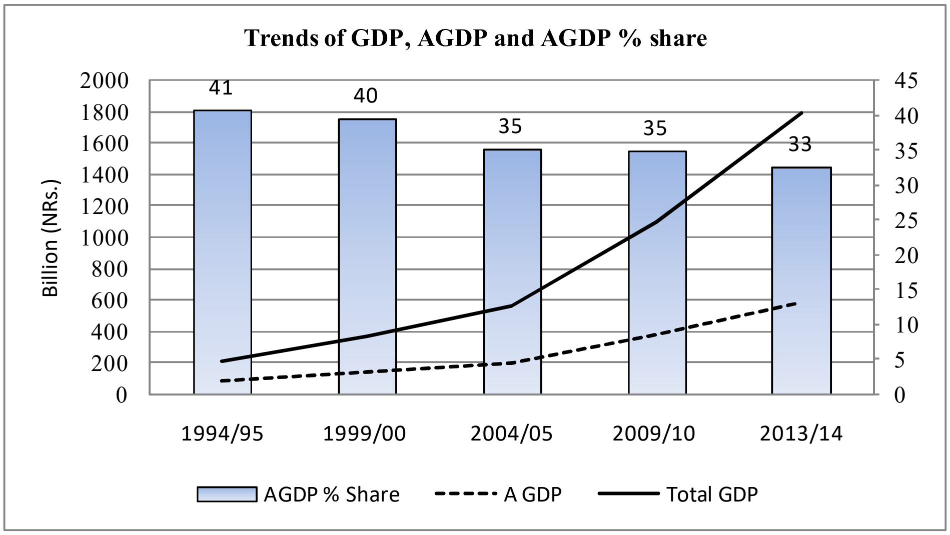
The paper aimed to evaluate the progress of agriculture sector in general and major sub-sector in particular and examined the effect of different factors on the growth of the overall agriculture sector (measured in term of AGDP) and yields of major crops. This paper is organized as follows. Section two is about the background information on Nepalese agriculture and its trend, section three is for methodology and data, section four explains the results and discussion and section five concludes the study by explaining its implications.

1. BACKGROUND OF NEPALESE AGRICULTURE

1.1 CHANGES IN SHARE OF AGRICULTURE IN GDP

In recent years, the nominal GDP and AGDP showed increasing trends in Nepal, whereas the gap between GDP and AGDP is widening. As a result, the share of AGDP to total GDP showed the decreasing trend. This is considered a global trend in developed and developing countries. In

Nepal, the nominal GDP rose by 9.32 times in 21 year period from 1993/94 to 2013/14, whereas the AGDP increased by 7.24 times only, in the same period (Figure 1). Likewise, the share of total employment by agriculture sector also showed the decreasing trend. The share was 83% in 1995/1996 and it decreased to 64% in 2010/11 (Figure 2). Similarly, the per capita GDP grew 3.83 times (USD 180 to USD 691) in 22 years from 1993 to 2014 (The World Bank, 2015).

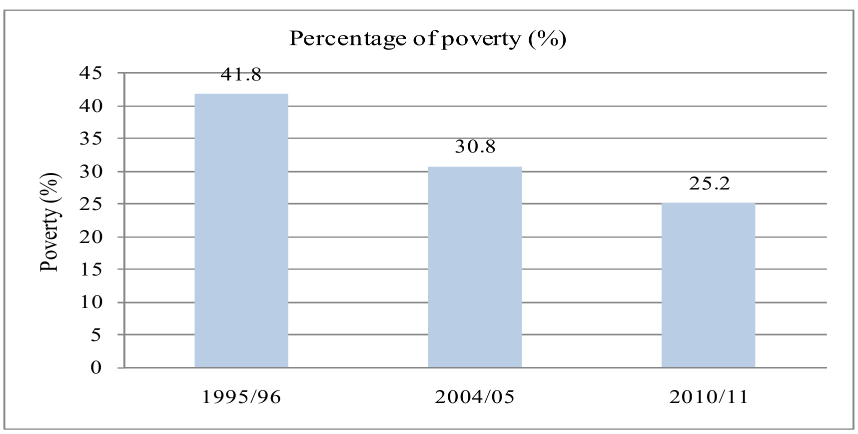


Source: MoAD, 2001/02-2013/14

Figure 1. Trends of GDP and AGDP in Nepal (1994/85 to 2013/14)

1.2 POVERTY TREND IN NEPAL

The poverty was noticeably declined from 42% to 25% in in the last 15 years, 1995/96 to 2010/11. Agriculture sector is considered one of the major sectors for the poverty reduction in Nepal, for example, the increase in the wages of agricultural labour and remittance among others are believed to be major causes of poverty reduction.



Source: CBS (NLSS),1996/96, 2003/04, 2010/11

Figure 2. Trends of poverty in Nepal

METHODOLOGY

Secondary data were used for the study. Ordinary least square (OLS) regression, i.e., the simple and multiple regression models were used for the analysis. These regression models have been used in agriculture for analyzing the effect of explanatory variables on the dependent variables (Wooldrige, 2009). Therefore, the simple regression model was used to evaluate the progress of agriculture in relation to time factor in the first stage. Further, a multiple regression model was applied using multiple explanatory variables in the second stage if yield showed significant progress with time variable in the first stage. The time factor is taken as a proxy indicator to represent the change in technology and management aspects over the years.

The simple OLS model is,

$$Y_{it} = \alpha + \beta X_{it} + u_{it} \qquad (1)$$

Where $Y_{it}$is AGDP to represent overall agriculture growth and yields of study crops X_{it}istime variable to represent the spontaneous technological and management change over the years, α_1 and β are regression coefficients. The error term u_{it} is i.i.d, μ=0, σ^2=1.

In the second stage, the effect of multiple explanatory variables on AGDP and yield of major crops was examined. This method has been used by different scholars in similar studies. This study assumed that fertilizer, irrigation, time factor to represent technological and management change, government investment, and rainfall are very much important for the agriculture development. Those variables are frequently used in the analysis of yield growth.

The multiple OLS model is,

$$Y_{it} = \alpha_1 + \beta_1 X_{1t} + \beta_2 X_{2t} + \beta_3 X_{3t} + \beta_4 X_{4t} + \beta_5 X_{5t} + e_{it} \qquad (2)$$

Where, Y is total annual AGDP and yields (Kgha^{-1}yr^{-1}), i represent rice, maize, wheat, vegetables, potato, and fruit and$t$ represents the time factor. In this equation, X_1, X_2, X_3, X_4 and X_5 represent time, irrigation (ha), fertilizer (Mt), government expenditure in agriculture (million NRs.) and rainfall (mm) respectively and α,β_1, β_2, β_3, β_4, and β_5 are respective regression coefficients.The error term e_{it} is i.i.d, μ=0, σ^2=1.

Six crops such as rice, maize, wheat, potato, vegetables and fruits were selected for the study. The basis of selection is contribution of crops in AGDP. The share of rice, maize, wheat, potato, vegetables and fruits on total AGDP are 20.75, 6.88, 7.14, 9.17, 4.67 and 7.04 %, respectively (MoAD, 2013/14). The livestock sector has also good contribution in AGDP, however, this was not included in the study due to lack of productivity figures in the publication.

DATA

This study considered irrigation, fertilizer, government expenditure and rainfall as explanatory variables that may effect on overall agriculture development as AGDP and the yields of the study crops. In addition, the study also considered time variable as a proxy variable to represent the gradual advancement of agricultural technology and management in the country.

The data for yields of rice, maize, wheat, potato, vegetables, fruits, irrigation (ha), fertilizer (Mt), expenditure on agriculture (Million NRs) and agriculture gross domestic products (AGDP) were obtained from yearly issues of Statistical Information on Nepalese Agriculture (1993/94-2013/14) published by the Ministry of Agricultural Development (MoAD). Likewise, the rainfall (mm) data from 1993 to 2012 were obtained from The World Bank website. The rainfall data of the World Bank were used because such data were not available in local sources for those years. The remaining data for the years 2013 and 2014 were obtained from MoAD by averaging monthly data from 21 stations distributed in different locations of the country.

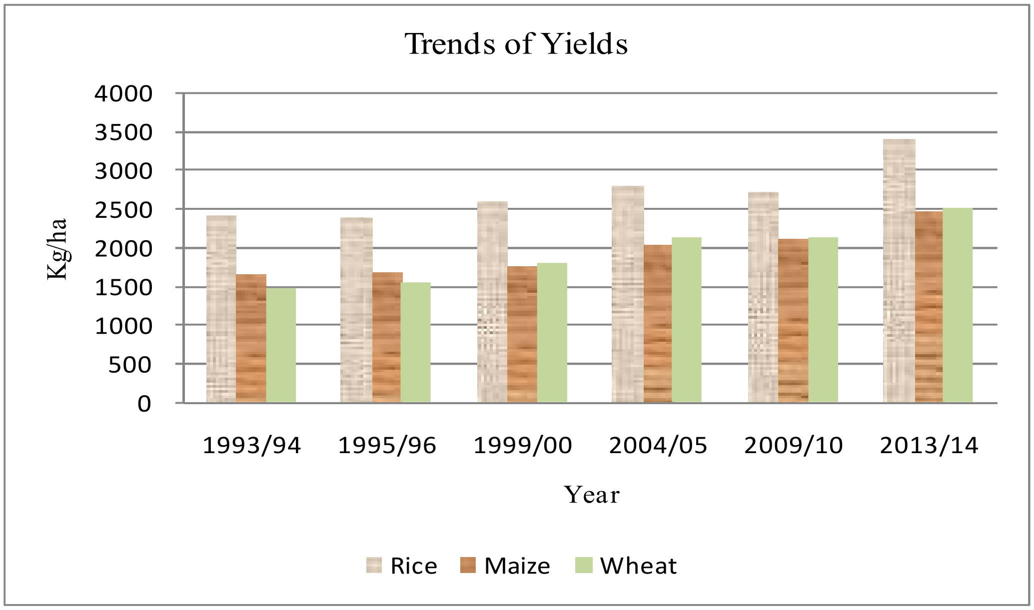
The yield data used for this study were national annual average yield ($Kgha^{-1}$) of the respective crops from 1993/94 to 2013/14. Likewise, fertilizer (Mt) data were total chemical fertilizer sold in the country. It was assumed that purchased fertilizers were used for the major crops, which ultimately helps to increase the yield. Irrigation is considered an important factor for crop yield growth in Nepal because more than 50% land is still rain fed. In Nepal, only 1,363,701 ha land is under irrigation, therefore, the study assumed that rainfall is important for crop yield growth as well as the overall agriculture growth of the country. In case of government expenditure, it was assumed it will help to generate new technology, good extension services, marketing support services and other enabling environment. Thus, it was considered that a higher government expenditure has positive effect on overall agriculture growth and individual crop yields. Given the shortness of data, Unit Root test for the stationarity of the data were not performed. The descriptive statistics are explained in the Table 2.

Table 2. Descriptive statistics of study variables (1993/4 – 2013/14)

Variables	Observation	Average	Max.	Min.	STD	Skew	Kurtosis
Rice Yield(Kg/ha)	21	2721	3394	2124	314	0.494	0.247
Maize Yield(Kg/ha)	21	1975	2501	1659	275	0.502	-0.964
Wheat Yield(Kg/ha)	21	1968	2496	1470	320	0.020	-1.068
Vegetable Yield(Kg/ha)	21	11119	13463	8523	1622	-0.027	-1.223
Potato Yield (Kg/ha)	21	11306	13735	8352	2084	-0.211	-1.653
Fruit Yield(Kg/ha)	21	9772	10172	8766	413	-1.129	0.397
AGDP (M)	21	243291	583692	80589	159201	1.069	-0.175
Govt. Expenditure(M)	21	4700	15867	1965	3904	1.672	2.190
Irrigation(ha)	21	1005705	1363701	599464	197952	0.068	-0.175
Fertilizer(Mt)	21	125741	232189	10329	53076	-0.658	0.912
Rainfall(mm)	21	1254	1772	1043	158	2.035	5.223

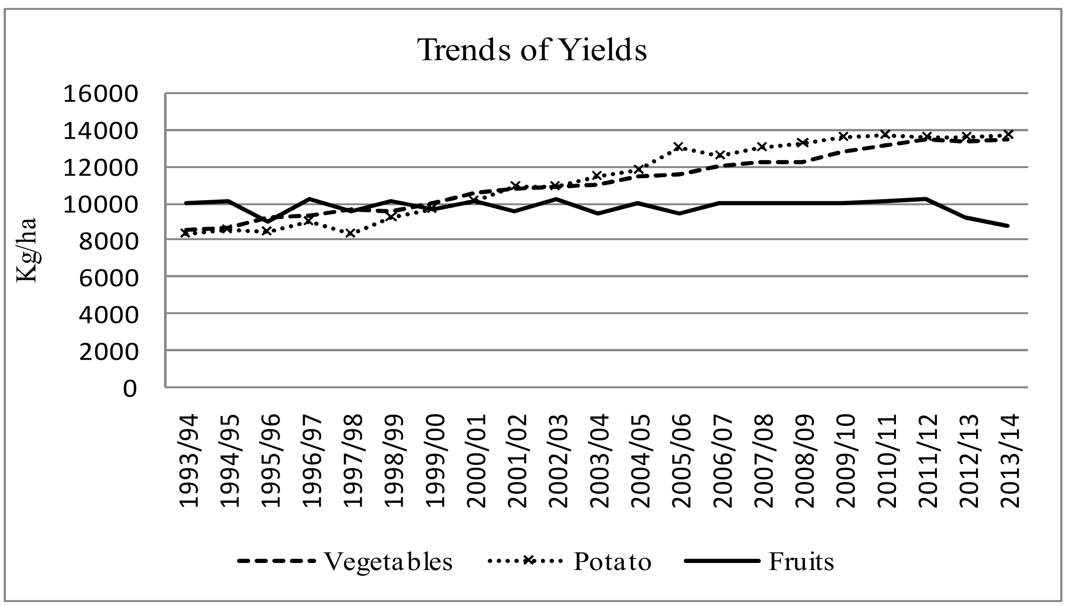
Source: MoAD (1993/4 – 2013/14); The World Bank (2015)

The trends of rice, maize, and wheat yields are shown in Figure 3 and the trend of vegetables, potato and fruits are shown in Figure 4. From the figure 3 and 4, it can be easily noticed that yield growth is visible in five crops. The yields for all crops except fruits showed increasing trends in Nepal during 1993/94 to 2013/14.



Source: MoAD(1993/93-2013/14)

Figure 3.Trends of rice, maize and wheat yields in Nepal



Source: MoAD(1993/93-2013/14)

Figure 4.Trends of vegetables, potato and fruit yields in Nepal

RESULTS AND DISCUSSION

SIMPLE REGRESSION

The simple regression was used to analyze the effect of time (a proxy indicator of technology and management) on overall agriculture growth as AGDP and yields of six major crops in Nepal. The regression results obtained are presented in Table 3.

The rice yield showed positive and statistically significant result with time variable and yield growth was 45 $kgha^{-1}yr^{-1}$ during the study period. The growth rate was substantial (>33.1 $kgha^{1}yr^{-1}$) as explained by Hafner (2003). According to Hafner (2003), 33.1 $kgha^{1}yr^{-1}$cereal yield growth is needed to feed 9 billion people that are projected in 2050. In maize, the yield was positive and significant in response to time variable with the growth of 42.59 $kgha^{1}yr^{-1}$. The wheat yield was significant i.e., 49.54 $kgha^{1}yr^{-1}$. Thus, all major cereals showed significant progress for annual yield increment in Nepal. Similarly, potato and vegetables yield were also observed significant by 326.32 and 260.14 $kgha^{1}yr^{-1}$ respectively. However, the increment in fruit yield was not statistically significant with the time variable indicated during the study period. The overall agriculture sector growth represented by AGDP in this study showed a significant positive increment over the years. The result showed AGDP grew by NRs. 23,655.44 million in nominal value per annum. The significant variables were analyzed further by using multiple regression analysis.

Table 3. Results of simple regression model

Variables	*a*	*B* (time)	R^2
Rice	2224.91*** (66.54)	45.08*** (5.29)	0.79
Maize	1504.65*** (32.57)	42.59*** (15.20)	0.93
Wheat	1423.34*** (40.77)	49.54*** (3.25)	0.92
Vegetables	8257.55*** (72.31)	260.14*** (5.76)	0.99
Potato	7716.66*** (228.24)	326.32*** (18.17)	0.94
Fruit	9881.17*** (189.47)	-9.97 (15.09)	0.02
AGDP	-16918.49 (28623.17)	23655.44*** (2279.54)	0.85

Note: ***, **, and * represent significance at .01, .05, and .1 level respectively. Numbers in parentheses are standard errors Source: Author's estimation

Multiple regressions

In this model, five independent variables such as, time, fertilizer, irrigation, government expenditure and rainfall were used to examine their individual effect on dependent variables i.e. AGDP and yields of rice, maize, wheat, potato and vegetables. The multiple regression model was applied using equation (2). The results are presented in Table 4.

(i) Rice

The model for rice yield showed F-statistics (21.06) significant at 0.01 level and R^2 value 0.88, which indicated the model fitted well. However, the results showed no significant effect of all explanatory variables on rice yield. The individual effect of time in this model was observed 45.27 $kgha^{-1}yr^{-1}$, which is slightly greater than the result obtained in the simple regression model; however, it showed no statistically significant result. The R^2 value also is seen greater in a multiple regression model as compared simple regression model. The reason behind with no significant result of time on rice yield in a multiple regression model could be due to interaction effect of all explanatory variables.

(ii) Maize

The multiple regression models for maize yield showed F-statistics (75.68) significant at 0.01 levels with R^2 value 0.96. This indicates the explanatory variables could explain maize yield in this model. Of the five explanatory variables examined, two variables, i.e., time and government expenditure showed positive and statistically significant results at 0.05 and 0.01 levels, respectively. The results were as expected. The government expenditure coefficient showed 0.02, which indicates every million NRs. investment by government increase yield by $0.02kgha^{-1}yr^{-1}$. The higher government expenditure supports on research, extension, and other support services, was helpful to increase the yield level in Nepal. Likewise, time represents the technology and management over the year is assumed to be helpful to increase the yield level.

(iii) Wheat

The multiple regression models for wheat yield showed a significant F-statistics (90.47) at 0.01 level and R^2 value 0.97. This indicates wheat yield model was explained well by the explanatory variables. The coefficient of time and fertilizer variables showed positive and significant result at 0.01 levels and the rest of explanatory variables showed statistically no effect on wheat yields. The coefficient of time variable showed $76.21kgha^{-1}yr^{-1}$, which is noticeably larger than the result observed in the simple regression model, i.e., $49.54kgha^{-1}yr^{-1}$. The increase in value of the time coefficient could be due to the mix effect of four explanatory variables applied in this model. In case of fertilizer, the coefficient value was observed minimal.

(iv) Vegetables

In the case of vegetables, the R^2 value of the multiple regression model was observed 0.99 and the F-statistics (480.37) is seen significant at 0.01 level. Thus, the model fitted to the vegetables yield of Nepal was explained well by the explanatory variables. Three explanatory variables, i.e., time, irrigation and rainfall showed statistically significant results at 0.01, 0.1 and 0.1 levels respectively. The result showed a positive effect by time and irrigation and negative effect of rainfall. The coefficient of time, irrigation and rainfall were 194.60, 0.00, and -0.90 respectively. The result showed vegetable yield was increased by $194.60kgha^{-1}$every year due to time effect, minimal (zero numbers for two decimal digits) increased in yield due to expansion of irrigated areas in hectares and a reduction in $0.9kgha^{-1}$ as 1mm average rainfall increased in the country. The result of time and irrigation was observed as assumed, however, the result of a negative effect of rainfall was contrary to assumption. In the case of irrigation, different vegetables are grown round the year in Nepal by rotation in different agro-ecological zones. Twenty percent of total annual average rainfall is distributed for 8 months (Oct, Nov, Dec, Jan, Feb, Mar, Apr, and May) in Nepal. Thus, irrigation is crucial for vegetable growing in those dry months. The unexpected result observed due to rainfall on vegetable yield could be the effect of excess rainfall impairing fertilization during rainy season. In Nepal, on an average 80% rainfall of total annual rainfall occur during 4 months i.e., June, July, August, and September. Thus, vegetables grown in those four months could show a negative effect on yields.

(v) Potato

In the case of potato, similar result like that of vegetables was observed. The R^2 value of the multiple regression model was observed 0.98 and the F-statistics (168.11) is seen significant at 0.01 level. Thus, the model fitted to the potato yield of Nepal was explained well by the explanatory variables. Three explanatory variables, i.e., time, irrigation and rainfall showed statistically significant results at 0.01, 0.05 and 0.1 levels respectively. The result showed a positive effect of time and negative effect of irrigation and rainfall. The coefficient of time, irrigation and rainfall were 938.99, -0.01, and -1.92 were, respectively. The result showed potato yield was increased by 938.99 $kgha^{-1}$ every year due to time effect, a minimal (-0.01 $kgha^{-1}$) decreased in yield due to expansion of irrigated areas in hectares and a reduction in 1.92 $kgha^{-1}$ as 1mm average rainfall increased in the country. The result of time was observed in line with the assumption, however, the result of negative influence of irrigation and rainfall was contrary to expectations. In the case of irrigation, potato is grown round year in Nepal by rotation in different agro-ecological zones. Twenty percent of total annual average rainfall is distributed for 8 months (Oct, Nov, Dec, Jan, Feb, Mar, Apr, and May) in Nepal. Potato is grown in high hills in rainy season in Nepal. Hills are the major potato growing areas in Nepal. Thus, results of rainfall and irrigation that were observed on potato yield could be the effect of excessive rain in high hills in rainy season. Tiwari et al. (2015) showed similar results of negative influence of rainfall in potato yield grown in winter season in Banke district in Nepal.

(vi) AGDP

The overall agriculture growth is represented by AGDP in this study. The result showed F-statistics (158.61) significance at 0.01 level and R^2 value 0.98. This indicates that the model fitted well with explanatory variables. Of the five variables, 3 variables, namely, irrigation, expenditure, and rainfall showed significant result sat 0.05, 0.01, and 0.05 levels respectively. The coefficient of irrigation, expenditure, and rainfall were 0.39, 30.34, and -201.07 respectively. Expansion of irrigated area was seen helpful for overall economic growth. The result illustrated that one additional hectare irrigated land expansion contributed to 0.39 million addition in AGDP for the country. The result is in line with the assumption. Likewise, government expenditure on agriculture showed positive result showing one million rupees investment in agriculture generated 30.34 million rupees AGDP. Based on the results, agriculture could be very attractive investment option for the Government of Nepal.

In this model, the negative coefficient was observed for time variable butit was not statistically significant. This indicated that AGDP growth was not contributed by time factor, which was opposite to the assumption. Likewise, the rainfall coefficient illustrated negative effect that indicated a negative effect of rainfall on overall agricultural growth. The observed result contradicted with Acharya and Bhatta (2013). The authors presented that rainfall had positive effect on AGDP in Nepal. The differences in observed result could be the effect of variation in the period and sources of the data. Their data were for longer period of 36 years, 1975 to 2010 while the data of this study were only for 21 years, 1993/94 to 2013/14. Additionally, they applied an average rainfall data from

15 stations whereas the current study applied first 19 years' data from the World Bank source and the last two years data from Nepal (the average of 21 stations). Thapa et. al. (2015) presented that precipitation influenced the net farm income in a mixed way, i.e., positive influence in hill and negative in Terai (Southern plane area) which supports the results of this study in some way because Terai region is the major contributor to AGDP in Nepal.

Table 4. Results of multiple regression model

Variables	α_1	time (β_1)	Irrigation (β2)	Fertilizer (β_3)	Expenditure (β_4)	rainfall (β_5)	R^2
Rice	1609.23**	45.27	0.00[1]	0.00[1]	0.01	0.36	0.88
	(585.00)	(31.44)	(0.00)	(0.00)	(0.20)	(0.39)	
Maize	1941.11***	49.71***	0.00[1]	0.00[1]	0.02**	-0.10	0.96
	(282.69)	(15.20)	(0.00)	(0.00)	(0.01)	(0.19)	
Wheat	1548.72***	76.21***	0.00[1]	0.00***,1	-0.02	-0.10	0.97
	(301.94)	(16.23)	(0.00)	(0.00)	(0.01)	(0.20)	
Vegetables	8160.60***	194.60***	0.00*, 1	-0.00[1]	0.03	-0.90*	0.99
	(673.42)	(36.20)	(0.00)	(0.00)	(0.02)	(0.44)	
Potato	13159.50***	538.99***	-0.01**	0.00[1]	-0.03	-1.92*	0.98
	(1454.29)	(78.17)	(0.00)	(0.00)	(0 .04)	(0.95)	
AGDP	-22619.38	-1331.91	0.39**	0.01	30.34***	-201.07**	0.98
	(114339.10)	(6146.40)	(0 .18)	(0.17)	(3.85)	(75.24)	

Note: ***, **, and * represent significance at .01, .05, and .1 levels respectively. Numbers in parentheses are standard errors and [1] is for zero numbers for two decimal digits

CONCLUSION AND POLICY IMPLICATIONS

Agriculture is the mainstay of Nepal, however, its share in GDP and employment has been declining over the years. The declining share of agriculture in GDP is seen evidently as the country shows progress in the development. Agriculture sector in overall and its major contributing sub-sectors, such as cereals, vegetables, potato and livestock showed noticeable progress in the area and production in Nepal. The per capita income of the people particularly those of agriculture labour increased in the country. Consumption pattern of food items was observed slightly changed to more nutritious food, i.e., increased the amount of the meat, fish, vegetables and fruits in the diet. The intake of protein and calories in the food of the family improved. As a result, the food and nutritional security situation was observed improved in the country. The growth of agriculture sector in Nepal could be one of major reasons for poverty reduction to 25.2% in recent years.

AGDP growth was taken as the indicator of overall agriculture sector in this study whereas productivity increment was employed as an indicator of growth of sub-sectors, such as, rice, maize, wheat, vegetables, fruits, and potato. Despite the major contribution of livestock sector in AGDP, the study was unable to include this sector due to lack of productivity figures in the time series data. The study evaluated the growth of overall agriculture sectors including major sub- sectors using simple regression model in reference to time variable. Besides fruit, all examined variables showed statistically significant progress over the years. Thus, it could be concluded that major sub-sectors of agriculture and the overall agricultural sector have been progressing well in recent years in Nepal.

Further analysis was made applying five explanatory variables, i.e., time, fertilizer, irrigation, government, expenditure, and rainfall. The analysis was done by using multiple regression models to identify significantly contributing variables in the success of agriculture. The results showed no influence of all the explanatory variables used despite the good coefficient value of time variable on rice yields. Time and government expenditure were seen to positively influencing the growth of maize yield, therefore, increasing government expenditure in agriculture could be helpful to increase the yield level in maize. Similarly, yields of wheat were positively affected by fertilizer, which indicates that increasing the supply of fertilizer in the market and encouraging the farmers to use more fertilizer for wheat crop should be helpful to attain higher level of yield. Irrigation was observed positively influencing the vegetable yield, but rainfall showed the opposite result for the same. Moreover, similar unexpected results obtained in the case of potato yield growth as both irrigation and rainfall showed the negative influence on yield level. Indeed, this result was unexpected and should be verified further. In case of overall agriculture growth, irrigation and expenditure showed positive influence, while rainfall showed negative results. The result explicitly presented that one additional hectare expansion of irrigated land and one million NRs. investment in agriculture contributed to 0.39 million and 30.34 million additions to AGDP, respectively. Therefore, investment in agriculture is seen an attractive option to increase the AGDP in Nepal.

The observed negative results of irrigation in potato yield and negative influence of rainfall in vegetable, potato and AGDP is indeed an unexpected result. Therefore, it should be cautious while interpreting and before implementing the results. Importantly, time variable which represents the technology and management factor was seen influencing to maize, wheat, vegetable, and potato yield. Thus, further research is necessary to disintegrate the effect of technology, management, and inputs.

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DETERMINANTS OF PESTICIDE APPLICATION IN NEPALESE VEGETABLE FARMING: AN EMPIRICAL ANALYSIS USING MULTIVARIATE PROBIT MODEL

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ABSTRACT

Currently, the pesticides are the global core concern because it is a boon to farmers against increasing disease-pest and simultaneously, pesticide residue is the major anxiety regarding human health. For that reason, identification and determination of factors affecting the application of pesticides are essential. To identify and evaluate determinants of pesticides application in Nepal, a household survey of 300 households was carried-out and an empirical analysis was performed using multivariate probit model. Moreover, powder and liquid forms of pesticides were considered for summer and winter season in vegetable farming, which was assigned as outcome variables. Likewise, socio-economic, demographic, farm-level and perception data were considered as explanatory variables. Use of chemical fertilizers, age and gender of household head, household size and access to weather information were found the most influencing factors. Moreover, forms of pesticides and growing seasons were found complementary to each other. Therefore, devising the policy options accordingly should balance needs of farmers and health of consumers.

Key words: Determinant, multivariate probit model, Nepal, pesticides, vegetable

INTRODUCTION

Nepal is an agrarian country having one-third contribution to Gross Domestic Product (GDP) from the agriculture sector and retaining two-third labour force in it (MoF, 2016). Although cereal crops are the major produces in Nepalese agriculture system, occupying 280 thousand hectares, as of 2015/016, the vegetable is one of the significant crop (MoAD, 2017). Moreover, an area of vegetable has increased by 99.86% from 1991/92 to 2015/016 (MoAD, 2017), and importantly, vegetable farming is one of the major sink of pesticides in Nepal (Atreya et al., 2012).

Pesticide use in Nepal has started since 1952 with an introduction of Paris green, Gammexane and Nicotine Sulphate (Sharma, Thapa, Manandhar, Shrestha, & Pradhan, 2012). Since then, pesticides became one of the priority input in the modern agriculture to raise production by fighting against disease-pest. Another important fact, the losses of crops due to storage and pest were estimated around 30% (Palikhe, 2002; Paneru et al., 1977). If only these losses could be reduced, there would be a considerable increase in availability of food, and thus contributing to the food security (FAO, 2017).

The use of pesticides pound the adverse effect on the human health, land and environment (Gayatri et al., 2016). Likewise, yield loss due to non-target pesticide application resulted in pesticide induced pest resurgence and increasing financial burden to the farmers (Wilson and Tisdell, 2001). Thus, the use of pesticides has both positive and negative externalities. Farmers are applying chemical pesticides at high dose and frequency, and cocktail spray (Aryal, 2014) because of lack of

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awareness regarding the harmful effects such as cancer, improper fetal development, Parkinson's disease, birth defects, altered growth, acute and chronic toxicity.

Though several studies have carried out regarding uses of pesticide but best on knowledge, none of the studies has been done to determine factor influencing the choice of application of pesticides. Thus, the study aimed to evaluate determinants of pesticides application in vegetable farming in Nepal and calculate its marginal effect. It enables policymakers in order to devise policy which balances purpose of plant protection and concern of public health and environment.

PESTICIDES CONSUMPTION IN NEPAL

Even though majority of pesticides are consumed in the developed countries, the developing countries are increasing its use. In Nepal, aggregate consumption of pesticides is 396g a.i./ha (PRMS, 2014), which is higher than the previous record 142g a.i./ha (Diwakar et al., 2010). However, it is still lower than the other Asian countries like India, Japan, China, and Korea, which consume 0.5, 12, 14 and 6.6 kg/ha, respectively, and other advanced countries like the USA and the Europe - 7.0 and 2.5kg/ha, respectively (Atreya, 2007).

On ecological basis, the highest average pesticide is used in the Terai region of Nepal i.e. 0.995 a.i. kg/ha followed by valley 0.470 a.i. kg/ha, hill 0.314 a.i. kg/ha and lowest in the high hill 0.085 a.i. kg/ha (PRMS, 2014). Similarly, heavy pesticide use was found in the Central Development Region (1.015a.i. kg/ha) followed by Eastern Development Region (0.616 a.i. kg/ha), Western Development Region (0.276 a.i. kg/ha), Mid-Western Development Region (0.225 a.i. kg/ha) and least in the Far-Western Development Region (0.146 a.i.kg/ha) (PRMS, 2014).

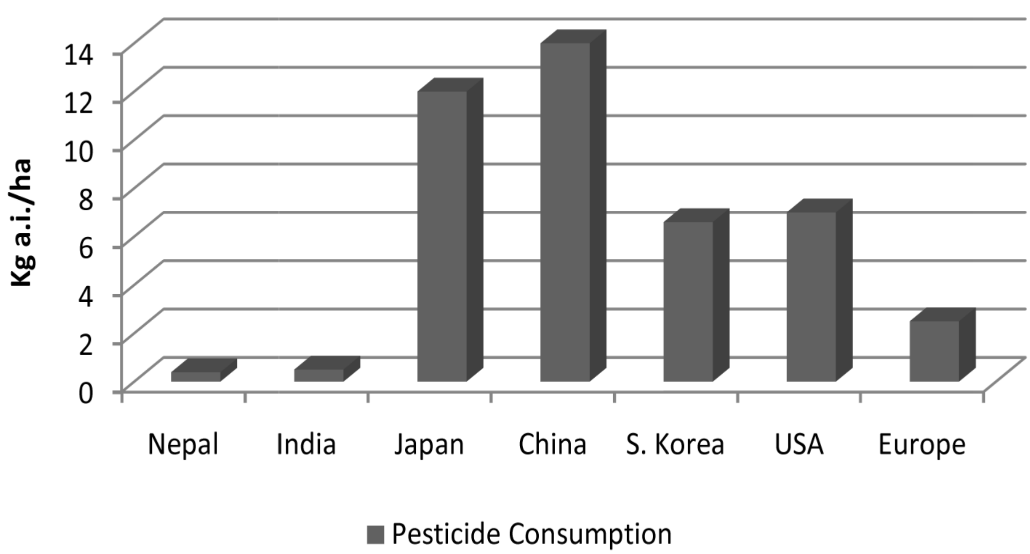

Figure 1. Comparison on national consumption of pesticide

USES OF PESTICIDES IN DIFFERENT CROP

The highest share of pesticides was found in vegetables, which accounts for 89% of the total pesticide use followed by cash crops and found least in cereals as shown in Table 1.

Table 1. Consumption of pesticide by crop type

S.N.	Crops	Quantity a.i.kg/ha
1	Cereals	0.05
2	Vegetables	1.60
3	Cash crops	0.19
4	Pulses	0.05
5	Fruits	0.03

Source: Survey Report on National Pesticide Consumption Statistics in Nepal, 2014

METHODOLOGY

DATA AND STUDY LOCATION

A household level survey was carried out in 300 households covering 10 sample districts by random sampling technique. The sample districts were selected to cover all five geographical regions – High Mountain (Mustang), Mountain (Kaski and Rasuwa), Hill (Rolpa, Dadhing, Dadeldhura and Terhathum), Siwalek (Chitwan) and Terai (Parsa and Bardiya).

EMPIRICAL MODEL

The multivariate probit model (MVP) is used to study the farmers' choices on pesticides application because it can capture latent effects among various choices, which cannot capture by other alternative models (Greene, 2000, Nhemachena et al., 2014, Piya et al., 2013). Moreover, powder and liquid forms of pesticides were considered for summer and winter season in vegetable farming, which were assigned as outcome variables rather than just pesticide. Likewise, socio-economic, demographic, farm-level and perception data were considered as explanatory variables, which are described in Table-2. The general specification for the MVP is (Greene, 2000).

$$Z = x'_m\beta_m + \varepsilon_m, \quad Z = 1 \; if \; Z > 0, \; otherwise \; 0, \quad m = 1, \ldots\ldots, M, \qquad (1)$$

$$E[\varepsilon_m | x_1, \ldots., x_M] = 0,$$

$$Var[\varepsilon_m | x_1, \ldots., x_M] = 1,$$

$$Cov[\varepsilon_j \varepsilon_m | x_1, \ldots., x_M] = \rho_{jm},$$

$$(\varepsilon_1, \ldots\ldots, \varepsilon_M \sim N_M[0, R]$$

Where x is a covariates matrix having any explanatory variables, β is a matrix of unknown regression coefficient and ε_m is a residual error. R is the variance-covariance matrix. The off-diagonal elements in correlation matrix ρ_{jm} represent the unobserved correlation between the stochastic component of the jth and mth options (Piya, 2013).

The marginal effects of explanatory variables on the propensity to adopt different pesticide options were calculated by following equation(Nhemachena et al., 2014).

$$\frac{\partial P_i}{\partial x_i} = \varphi(x'\beta)\beta_i, \quad i = 1,2,3, \ldots\ldots, n \qquad (2)$$

Where P_i is the likelihood of event i, which increases adoption of each pesticide forms, $\varphi(.)$ is the standard univariate normal density distribution function.

For this study, STATA 13 was employed and to get consistent estimates number of draws was set to 100, which is 5 by default (Cappellari, et. al., 2003; Piya, et. al., 2013).

VARIABLE DESCRIPTION

Two forms of pesticides – powder and liquid were considered as outcome variables for two seasons – the winter and the summer. All four outcome variables are binary variables, 1 for using the particular pesticide in the particular season and 0 otherwise. No theory has been developed regarding the selection of explanatory variables for the choice of pesticides uses. However, based on previous empirical analysis regarding pesticides and adaptation following explanatory variables has been selected for the model. The expected relationship between the explanatory and outcome variables is also presented in the Table-2.

Table 2. Variable description

Variables	Description	Mean	Expected relationship
WinPwd	Use of powder formulation of pesticides in winter crops; if YES = 1 otherwise 0	0 .46	NA
SumPwd	Use of powder formulation of pesticides in summer crops; if YES = 1 otherwise 0	0 .13	NA
WinLiq	Use of liquid formulation of pesticides in winter crops; if YES = 1 otherwise 0	0 .31	NA
SumLiq	Use of liquid formulation of pesticides in summer crops; if YES = 1 otherwise 0	0 .59	NA
WinFert	Use of chemical fertilizer in winter vegetable; if YES = 1 otherwise 0	0.69	±
SumFert	Use of chemical fertilizer in summer vegetable; if YES = 1 otherwise 0	0.69	±
Temp_CW	Perception of temperature change by farmers; if Cooler = 1 otherwise 0	0.88	±
SumVeg	Growing summer vegetable; if YES = 1 otherwise 0	0.24	+
WinVeg	Growing winter vegetable; if YES = 1 otherwise 0	0.47	+
GenderHoH	Gender of Head of Household; if Female = 1 otherwise 0	0.07	±
HHSize	Number of family member in a household	5.88	±
Weatherinfo	Having access to weather information; if YES = 1 otherwise 0	0.60	+
AgeHoH	Age of head of household in year	49.9	-
BorrowYN	Household having credit access; if YES= 1 otherwise 0	0.42	+
Extension1	Household having access to extension service; if YES =1 otherwise 0	0.79	+
Pest_MoreLess	Famers' perception on change in disease-pest incidence; if Increasing = 1 otherwise 0	0.07	+
FarmArea	Household farming area in hectare	0.93	±
EducHoH	Education level of head of household in school years	7.33	+
Drght_MoreLess	Famers' perception on change in drought frequency; if More = 1 otherwise 0	0.19	+
PctOnfarmIn come	Percentage of income coming from farming to total household income	69.99	±

RESULT AND DISCUSSION

The results from the MVP model showed that farmers growing the vegetable crops are highly likely to use pesticides. Interestingly, liquid-form of the pesticides are more likely to use in the winter vegetable, whereas, the powder form of pesticides are more likely to use in the summer vegetables. More importantly, farmers using chemical fertilizer are highly likely to use liquid pesticides in winter vegetables and powder form of the pesticides in the summer vegetables. However, farmers are less likely to use the powder form of the pesticides in winter vegetables if they are using chemical fertilizer, whereas, similar is the likelihood in the summer vegetables if they are using chemical fertilizers.

Table 3. The MVP model result

VARIABLES	WinPwd	SumPwd	WinLiq	SumLiq
WinVeg	0.38	-0.10	0.59**	-0.17
	(0.24)	(0.28)	(0.27)	(0.22)
WinFert	-0.82***	-0.02	1.44***	0.005
	(0.30)	(0.39)	(0.34)	(0.29)
SumVeg	-0.51*	0.74**	-0.27	0.22
	(0.27)	(0.32)	(0.33)	(0.27)
SumFert	0.12	0.98**	-0.70**	0.08
	(0.32)	(0.50)	(0.35)	(0.31)
Temp_C_W	-0.62**	-1.04***	-0.59*	-0.27
	(0.31)	(0.40)	(0.35)	(0.34)
Drght_MoreLess	-0.06	0.93***	-0.17	0.0004
	(0.28)	(0.31)	(0.33)	(0.29)
Pest_MoreLess	0.37	-0.36	1.69***	-0.05
	(0.38)	(0.47)	(0.45)	(0.42)
HHSize	0.06	-0.17**	0.035	0.07
	(0.04)	(0.07)	(0.05)	(0.04)
AgeHoH	-0.01	-0.03**	0.0006	-0.005
	(0.01)	(0.01)	(0.01)	(0.01)
GenderHoH	0.73	-5.56***	-0.66	0.40
	(0.47)	(0.63)	(0.47)	(0.47)
EducHoH	0.01	0.0001	0.01	0.023
	(0.02)	(0.03)	(0.03)	(0.03)
FarmArea	-0.12	0.40*	-0.10	-0.004
	(0.14)	(0.21)	(0.16)	(0.14)
PctOnfarmIncome	-0.0004	-0.0002	-0.002	-0.001
	(0.003)	(0.005)	(0.004)	(0.003)
BorrowedYN	0.25	0.61**	0.33	-0.11
	(0.23)	(0.30)	(0.24)	(0.23)
WeatherInfo	-0.27	0.59*	0.28	0.004
	(0.22)	(0.32)	(0.25)	(0.22)
Extension1	0.29	-0.14	0.77**	-0.007
	(0.28)	(0.35)	(0.34)	(0.26)

Constant	0.94	0.06	-1.80**	0.18
	(0.79)	(1.07)	(0.83)	(0.83)

(In parenthesis std. error are reported.***,** and * indicate significance at the 1%, 5%, and 10% levels respectively)

In case of perception of temperature change, if farmers perceived the temperature is going cooler, they are less likely to use pesticides, implying increasing temperature is also promoting the use of pesticides. Similarly, increasing frequency of drought in summer vegetables also highly likely to increases the use of powder form of the pesticides. Thus, it is also indicating that climate change is causing boosting of disease-pest, which increases the use of the pesticides. The results showed that winter pests are increasing than summer pest because increasing pest and use of liquid pesticides are highly significant in the winter vegetables.

Increasing number of member of the household is decreasing the likelihood of powder pesticides in summer and rest relations are not found significant. Similarly, young farmers are more likely to use pesticides as compared to old farmers. Likewise, female head of households are also less likely to adopt pesticides as compared to male counterpart. Importantly, role of the education was not found significant in any case. In case of farm area, only powder pesticides in summer vegetable were found significant and were positively associated, implying increasing area increases the likelihood of pesticide adoption.

Percentage of income coming from farming to total household income was not found significant. It implies that farmers are using pesticides irrespective of the share of farm income in their total household income. However, if the households have credit access, they are more likely to use the powder form of pesticides in the summer. Similarly, households having weather information are more likely to use the powder form of pesticides in the summer, whereas other seasons and forms were not found significant. Likewise, extension service is effective in winter to use liquid pesticides. If the households have access to extension services, they are more likely to adopt liquid pesticides in the winter.

CORRELATION COEFFICIENTS OF OUTCOME VARIABLES

One of the most important uses of the MVP is the capturing interaction among the outcome variables. The MVP results on correlation coefficients showed that the powder form of pesticides in winter vegetables and summer vegetables, the powder and liquid form of pesticides in the summer vegetables, the liquid form of pesticides in the winter and the summer vegetables are highly inter-related. More importantly, they are positively associated, indicating, they can be promoted or discouraged simultaneously.

Table 4. Correlation coefficients of outcome variables

	Rho1	Rho2	Rho3
Rho2	0.47***		
Rho3	-0.20	-0.17	
Rho4	0.07	0.44**	0.51***

(***,** and * indicate significance at the 1%, 5%, and 10% levels respectively)

MARGINAL EFFECTS

Without the marginal effects, the MVP can just calculate a likelihood of occurrence of the event. Thus, the marginal effect enables to quantify the impact of each explanatory variable in the model. The detail result of the marginal effect is presented in Table 5.

Table 5. Marginal effect

y = Linear prediction (predict) = -.11

variable	dy/dx	z	P>z	95%	C.I.	X
Win Fertilizer*	-0.82 (0.30)	-2.75	0.006	-1.40651	-0.236	0.691358
Temp Cooler or Warmer*	-0.62 (0.31)	-1.99	0.047	-1.24035	-0.00802	0.876543
Sum Veg*	-0.51 (0.27)	-1.93	0.054	-1.03357	0.008759	0.240741
Win Veg*	0.38 (0.24)	1.6	0.11	-0.0867	0.850763	0.469136
Gender HoH*	0.73 (0.47)	1.55	0.121	-0.19162	1.64749	0.061728
HH Size	0.06 (0.04)	1.46	0.145	-0.02187	0.148117	5.88272
Weather info*	-0.27 (0.22)	-1.22	0.224	-0.71054	0.166487	0.604938
Age of HoH	-0.01 (0.01)	-1.2	0.23	-0.032	0.007696	49.9877
Borrow Yes or No*	0.25 (0.23)	1.07	0.286	-0.20696	0.701696	0.419753
Extension*	0.29 (0.28)	1.05	0.295	-0.25152	0.829622	0.790123
Pest More or less*	0.37 (0.39)	0.97	0.331	-0.3797	1.12731	0.074074
Farm Area	-0.12 (0.14)	-0.87	0.386	-0.40264	0.155622	0.933765
Education of HoH	0.01 (0.02)	0.44	0.657	-0.02948	0.04672	7.33333
Summer Fertilizer*	0.12 (0.32)	0.37	0.708	-0.50222	0.739162	0.771605
Drought More or Less*	-0.06 (0.28)	-0.22	0.825	-0.61573	0.490928	0.185185
% On farm Income	-0.0004 (0.004)	-0.11	0.912	-0.00716	0.006393	69.9877

(*) dy/dx is for discrete change of dummy variable from 0 to 1 and In parenthesis std. error are reported

The results demonstrated that half of the variables are positively and half of the variables are negatively affecting the adoption decision for use of pesticides in general. The chemical fertilizer in the winter season was found the most influencing explanatory variable with a negative association. It means if farmers are using an appropriate amount of chemical fertilizer can reduce the use of pesticide significantly (-0.82) and similar is the case for temperature (-0.62). However, controlling temperature is not an easy task. Nevertheless, it suggests that production of vegetables in controlled environment – like the green house and the smart farming could reduce the use of the pesticide remarkably. Another interesting fact, the winter vegetable is consuming more pesticides than the summer vegetables. Further research is suggested to understand the detail about the finding. Despite the previous result of the negative association between gender and adoption of the pesticides, the marginal effect produced positive association, indicating being female as the head of household increases the likelihood of adoption of the pesticide by 0.73. Likewise, each year increase in the head of household decrease the likelihood of adoption of the pesticides by 0.01.

CONCLUSION

The determinants of pesticides application in Nepalese vegetable farming was identified and evaluated and the marginal effects of each explanatory variable were calculated. Disintegrating vegetable farming into the winter and the summer provides the deeper understanding of dynamics of use of the pesticides and further enriched by disintegrating pesticides into its two forms.

The winter vegetables are more likely to consume liquid forms of pesticides and the summer vegetables are more likely to consume powder form of pesticides. Interestingly, the use of chemical fertilizer is likely to produce different forms of the pesticides in the different season and simultaneously discouraging another form of the pesticides. The result supports to establish the relationship between the climate change and disease-pest, and suggests the promotion of technological advancement in vegetable farming, which could be the protected farming like the greenhouse or the smart farming. Similarly, household access to information is also influencing the farmers' decision on adoption of the pesticides thus the extension services can be used effectively to achieve the policy objective of the government. Likewise, very expectedly, household characteristics are influencing variables on the adoption. Finally, the correlation coefficients of the outcome variables are significant and positive, they can be promoted or discouraged simultaneously, which is an advantage to the government.

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MAD HONEY: FOOD, MEDICINE OR TOXIN? A FOOD TECHNOLOGY PERSPECTIVE

Krisha Pant[1]

ABSTRACT

Honey is an excellent source of nutrition and medicine. Some honey of wild origin contains hallucinogenic properties andis known as mad honey. The objective of this paper is to explore evidences on food values, medicinal values and poisonous effects of mad honey by reviewing available literature internationally. The 'madness' ofthe honey is due to the presence grayanotoxins from flowers of Ericaceae family: Rhododendron ponticum, R. flavum and other: Pieris japonica, Kalmia latifolia and Melicope ternate. In Nepal, mad honey is prepared by Apisla boriosa, which nest at mountain cliffs at high altitudes. The food value of mad honey and normal honey are similar. Literatures are available for the medicinal properties of grayanotoxin which are in use in folk medicines. Consumption of mad honey results intoxication, characterized by dizziness, hypotension and atrial-ventricular block. Awareness about the toxicity is necessary among the consumers of the mad honey.

Key words: Grayanotoxins, mad honey, Nepal, Rhododendron, wild honey

INTRODUCTION

Honey is the natural sweet substance produced by honeybees from the nectar of blossoms or from secretions of living parts of plants or excretions of plant sucking insects on the living parts of plants, which honeybees collect, transform and combine with specific substances of their own, store and leave in the honey comb to ripen and mature (CAC, 1987).Because of variation of origin of the flora or the nectar of the flowers that the bee utilizes, the honey showed variation in its physical and chemical properties such as pH, enzyme activities, ash contents, electrical conductivity and hydroxyl methyl furfural (Amabye and Mekonen, 2016).

Nepal is currently native to four species of honey bees out of eight commonly found among Asian countries, namely, *Apis cerana*, *A. florea*, *A.dorsata* and *A. laboriosa*. Among them, *A. cerana* is the common type of bee which makes series of parallel combs which enable them to rest in the man made shelters, whereas *A. laboriosa,* also called Himalayan cliff bee, prefers to nest in mountain cliffs at high altitudes ranging from 1200 to 3600 m. Honey made by the *Apisla boriosa*, the giant honeybee (*A.dorsata*) and the dwarf honeybee (*A.florea*) are referred as wild honey. The honey produced by *A. laboriosa* on the cliffs of mountains is known as mad honey from its toxic property and also red honey from its unique red colour (Figure 1).The mad honey is produced by *Apis laboriosa* from the nectar of rhododendrons flowers (Rhododendron spp), and from some other plants locally known as '*bikh*' (*Aconitum* spp) and '*pangra*' (*Entada scandens*) (Joshi, 2008). It is considered to be intoxicating and to have relaxing properties (Ahmad *et al*. 2003).

In the Himalayan mountain of Nepal, above altitudes of 2500m, Himalayan cliff bees build enormous nests on the overhanging cliffs. It showed that the majority of bee cliffs faced south-east

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and south-west, although some faced east and some faced west too. None of the cliffs faced north (Ahmad *et al.*, 2003). These huge nests, up to 5feet in diameter and containing up to 60kg of honey, are extraordinarily difficult to reach (Asher, 2014). But the honey inside is so valuable that many local people try anyway. The mad honey is named thus due to its characteristic hallu cinogenic property which originates from the bee pastures like nectars of rhododendron flowers (Asher, 2014). The leaves, flowers, pollen and nectar of many Rhododendron species contain toxic diterpenoids (gryanotoxins), found only in *Ericaceae* plants (Sutlupinar*et al.*, 1993) and these are the main compounds responsible for poisoning (Silici*et al.*, 2008). Other than rhododendrons, *Pieris*, *Agarista* and *Kalmia* also contain diterpenes grayanotoxins responsible for poisoning (Jansen *et al.*, 2012). The rhododendron species like *Rhododendron ponticum* and *R. luteum* contains a type of toxin in their nectar known as grayanotoxin, a natural neurotoxin. Out of 700 types of rhododendron species throughout the world, only few (2 or 3) species contain this type of toxin. In the highlands of the Himalayas; Bhutan, Yunnan (China), India and Nepal, the rare Himalayan cliff bee lives alongside Rhododendrons and frequently collects nectar from their poisonous flowers (Asher, 2014).

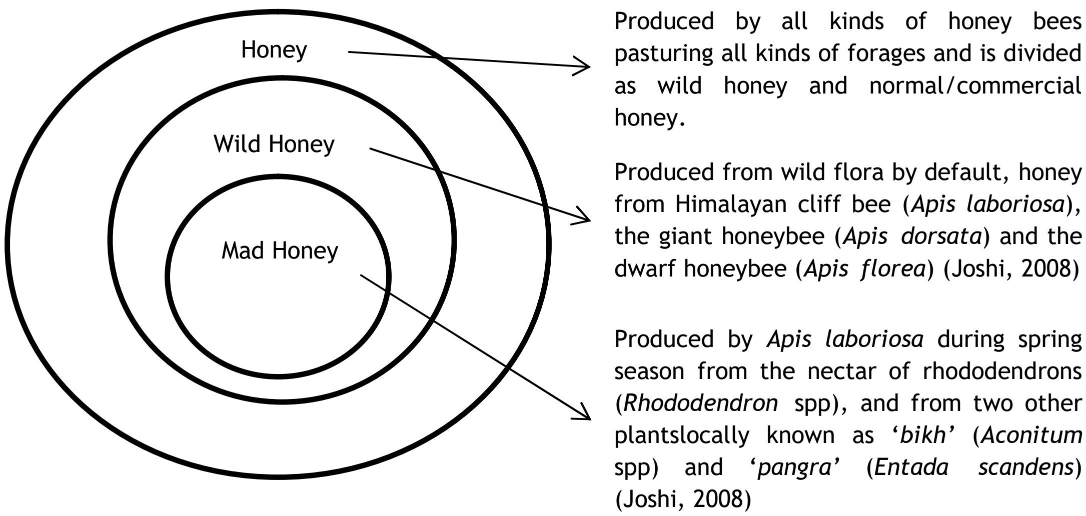


Figure 1. Honey, wild honey and mad honey

The objective of this study is to review food properties and medicinal properties of the mad honey and synthesize the findings on its hallucinogenic properties. The paper also explains the reasons behind such properties of honey. This paper is mainly based on review of secondary sources. The study have done on the basis of reviewing of published reports, documents, articles and presentations of researchers working in the field of wild honey. Data from researches completed in countries of the world like Nepal, Turkey, South Korea, Ethiopia and Nigeria have been included and explained in the study.

MAD HONEY AS FOOD

According to Codex Alimentarius Commission, food means any substance, whether processed, semi-processed or raw, which is intended for human consumption, and includes drink, chewing gum and any substance which has been used in the manufacture, preparation or treatment of "food" but does not include cosmetics or tobacco or substances used only as drugs (CAC, 2001). Honey as a food comprises mainly of carbohydrates, fructose (38%) and glucose (31%), which together make up nearly 70%, followed by about 20% water, and small amounts of an array of substances such as sucrose (0 – 2%), and traces of heavy metals, proteins (0.3%), ascorbic acid, flavonoids, enzymes, vitamins, etc. (Legesse, 2013).

Food value of honey is reported from Kaski district of Nepal comparing honey of *Apislaboriosa* and *A. cerana*. Though the honey from these two species is similar in composition, the honey from *A. laboriosa* is more acidic than that of *A. cerana* (Table 1). The analysis does not give any results on grayanotoxin content of honey.

Table 1. Proximate composition of *Apisla boriosa* and *Apiscerana* Honey Samples Collected from Kaski District, Nepal

Parameters	*Apis laboriosa*	*Apis cerana*
Moisture (%)	20.16 ± 2.94	18.78 ± 1.85
Fructose (g/100g)	37.06 ± 3.55	37.88 ± 0.81
Glucose (g/100g)	30.72 ± 2.97	31.64 ± 1.74
Sucrose (g/100g)	2.79 ± 0.76	3.57 ± 0.69
Maltose (g/100g)	0.74 ± 0.63	0.76 ± 0.51
Hydroxymethy furfural (mg/kg)	5.65 ± 12.55	6.99 ± 2.03
Acidity (meq/kg)	14.59 ± 4.826	9.03 ± 4.57
pH	3.96 ± 0.22	5.13 ± 0.70
Fructose: Glucose ratio	1.20 ± 0.4	1.19 ± 0.6

Source: Joshi, 2008

All the types of honey, wild or not, contains nutrients especially as energy provider sugar, vitamin C and phenolic compounds which having medicinal importance. The mad honey has similar food value as that of other commercial honey. But the presence of the grayanotoxins and low production fetches premium price.

MAD HONEY AS A MEDICINE

The communities native to the districts where mad honey is harvested, use it in small quantities for the treatment of various diseases including hypertension and diabetes (Sayin *et al.*, 2011).The exact dose that causes the poisoning is not known, but it is reported that the average amount of ingested honey needed for intoxication ranges from 5 g to 30 g (Yilmaz *et al.*, 2006). The severity of symptoms depends on the dose. Mad honey is often consumed for its believed medicinal potential (Aliyev *et al.*, 2009) and grayanotoxin containing herbal preparations are in use in traditional Chinese medicine as well. The mad honey intoxication cases demonstrate a clear effect of grayanotoxin on the heart with dramatic decrease in blood pressure and heart rate (Yilmaz *et al.*, 2006). In Turkey mad honey if used in small quantities is widely believed to promote general health.It is used as a pain reliever, for treatment of abdominal pain and dyspepsia, and felt to be a sexual stimulant (Gunduz *et al*., 2006).It is also believed in some communities that the honey promotes general well-being, including the treatment of gastric and coronary artery diseases, cold, and viral infection and as an analgesic (Scott *et al*., 1971). The scientific evidences to these claims are limited. Since the amount of grayanotoxin in mad honey is variable, accidental poisoning from intentional ingestion may occur (Scott *et al*., 1971).

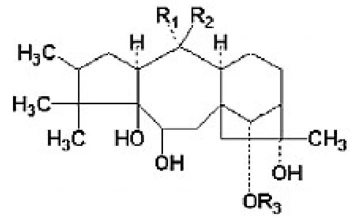
Despite this evidence of powerful anti-hypertensive action, the potential medical use of grayanotoxin itself, or new grayanotoxin analogs, in cardiovascular disease has not (yet) been fully investigated. On the other hand, the efficacy of grayanotoxin in diabetes treatment was shown in rats with streptozotocin-induced diabetes mellitus. Three days after streptozotocin treatment, blood glucose levels were measured just before and 1 h after administering grayanotoxin containing honey (50 mg/kg orally). Both in the control group as well as in the streptozotoc in-treated group, mean blood glucose levels decreased significantly (Jansen *et al*., 2012).In Nepal mad honey is mostly used as a hallucinogen and a recreational drug. The analytic evidence of the healing properties of mad honey from Nepal could not be found in literatures.

MAD HONEY AS A TOXIN

PRESENCE OF GRAYANOTOXINS IN HONEY

Plants contain numerous compounds that, when beneficial to humans, are categorized as ‘‘medicinal’’ and when harmful they are termed ‘‘poisonous’’. Secondary products derived from plants, such as honey, can contain a number of chemical compounds that, depending on their concentration and application, can also be considered medicinal or poisonous (Viuda-Martos *et al*., 2008). Grayanotoxins, also known as and romedotoxin, acetyl and romedol or rhodotoxin, can be derived from the leaves, twigs or flowers of plants belonging to genera of the Ericaceae (heath) family (Yilmaz *et al*., 2006), comprising among others the Rhododendron, Pieris, Agarista and Kalmia genera. The toxin is also present in a number of products originating from their family members, such as honey, Labrador tea, cigarettes and a variety of decoctions used in alternative medicine (Onat *et al*., 1991a). When bees ingest nectar containing grayanotoxin, the toxin, along with the other components of nectar is included in the honey which is produced. The complex sugars in nectar are enzymatically broken down into glucose and fructose in the bees’ second stomach (White and Doner, 2007). The honey is then secreted by the bees into the honey comb. Here forced evaporation removes water from the honey and concentrates all the components of the honey (Onat *et al*., 1991b).

More than 25 grayanotoxin iso forms have been isolated from Rhododendron (Qiang*et al*., 2011). Three members (GRAY1, GRAY2 and GRAY3) of the large grayanotoxin family (their chemical structure shown in Figure2) have been demonstrated to be of particular relevance in the reported clinical cases of mad honey poisoning (Wong *et al*., 2002). Grayanotoxin GRAY1 and GRAY2 have been found in the honey, leaves and flowers of *Rhododendron ponticum* and *R.flavum* as reported in multiple case reports in the eastern Black Sea area (Yilmaz *et al*., 2006). Grayanotoxin GRAY1 present in *Rhododendron simsii*, has been reported from a case in Hong Kong (Poon et al., 2008) while in the honey from Grouse Mountain, British Columbia, Canada, which causes a similar type of poisoning, only grayanotoxins GRAY2 and GRAY3 were found (Yavuz*et al*., 1991). Currently, grayanotoxin GRAY1 and GRAY3 are thought to be the principal toxic isomers (Gunduz *et al*., 2008).



GRAY	R_1	R_2	R_1R_2	R_3
GRAY1	OH	CH_3	-	H
GRAY2	-	-	$=CH_2$	H
GRAY3	OH	CH_3	-	Ac

Source: Gunduzet al., 2008

Figure2. Chemical structure of Grayanotoxin

EFFECTS OF GRAYANOTOXINS IN NEVOUS SYSTEM

In animal studies, Onat *et al.* (1991b) found that injecting a small dose equivalent to 50 mg of grayanotoxin containing honey intra-cerebroventricularly in anaesthetized albino rats caused marked bradycardia (very low pulse rate) and respiratory depression. However, a much larger amount of extract, equivalent to 1 and 5 g/kg, was needed intraperitoneally to obtain the same results. This might indicate the important role of the central nervous system in grayanotoxin pathophysiology compared to the peripheral nervous system. It was observed that atropine nullified both the grayanotoxin-induced bradycardia and respiratory depression, while AF-DX 16 only counteracted the bradycardic effect. From these results, Onat *et al.* (1991b) concluded that M2-receptor subtypes are involved in grayanotoxin-induced cardiotoxicity, but not in respiratory toxicity.

Lee *et al.* (2008) examined a total 111 samples (25 Korean honeys, 21 Korean wild honeys, 13 Korean honeycomb honeys, and 44 foreign honeys, 8 foreign wild honeys) to determine whether or not each sample contained grayanotoxins. Grayanotoxins were only found in the foreign wild honey and were not detected in Korean honey, Korean honeycomb honey, or Korean wild honey. Only three of the samples contained grayanotoxin GRAY1, GRAY2, and GRAY3 (Table 2). Through this study, safety management for foreign wild honey was enabled in Korea resulting into a need for accompanying grayanotoxin free certification with export of Nepalese honey to Korea. Similarly, Aygun *et al.* (2018) determined the grayanotoxins in mad honey collected from Black sea of Turkey. The grayanotoxin GRAY1 was found to be higher in the Korean study than in the Turkish study, whereas the levels of grayanotoxin GRAY2 and GRAY3 are much higher in Turkish study than in the Korean study. Currently, grayanotoxin GRAY1 and GRAY3 are thought to be the principal toxic isomers (Gunduz *et al.*, 2008). With the elevated amount of principle toxic isomers grayanotoxins GRAY1 and GRAY3 in the mad honey in Turkish study, the Turkish honey might be more toxic than that honey collected for studies in South Korea.

Table 2. Grayanotoxin levels in mad honey collected from South Korea and Turkey (mg/kg)

Grayanotoxins	South Korea		Turkey
	Lowest	Highest	
GRAY1	3.13 ± 0.00	12.93 ± 0.01	0.39 ± 0.46
GRAY2	0.84 ± 0.01	1.08 ± 0.01	8.73 ± 6.02
GRAY3	0.25 ± 0.01	3.29 ± 0.74	27.60 ± 18.98

Sources: Lee et al., 2008 and Aygun et al., 2018.

The level of grayanotoxins in the mad honey harvested from Nepal was not found in literatures. Due to the unstability of grayanoxin compounds on heating and having low vapor pressure during analyses, the grayanotoxin detection requires gas chromatography (GC) and slightly different gas liquid chromatography (GLC). The techniques for the detection and isolation of grayanotoxins in mad honey are summarized below in Box 1.

Box 1: DETECTION AND ISOLATION OF GRAYANOTOXINS IN HONEY

The grayanotoxin can be isolated from the suspect commodity by typical extraction procedures for naturally occurring terpenes, especially using methods valid for the lower terpenes (Harborne, 1998). Grayanotoxins, as diterpenes which are composed of four isoprene units having a molecular formula as C20H32 derived from geranylgeranyl pyrophosphate (GGPP), are less volatile than the sesquiterpenes and require some chromatographic techniques during detections. At the beginning of separation, paper electrophoresis (PE) and thin layer chromatography (TLC) is preferred for class separations. Gas chromatography (GC) and slightly different gas liquid chromatography (GLC) are often required, due to the compounds unstability (oxidize or decompose easily) on heating and having low vapor pressure during analyses. Hence, the compounds require derivatization before the GC or GLC analyses (Oztasan et al., 2005). Further identifications is largely based on infrared (IR), nuclear magnetic resonance (NMR) and mass spectrometry (MS) (Koca and Koca, 2007). In recent years, developed liquid-chromatography-mass spectrometry /mass spectrometry (LC-MS/MS) techniques are also in use in detection of the toxins in biological samples (Harborne, 1998).

INTOXICATION AND CLINICAL CHARACTERISTICS OF MAD HONEY POISONING

Mad honey from different parts of the world is nowadays available through online purchase. The price of mad honey is higher than that of the normal honey. Due to the lack of record for production and consumption of mad honey in Nepal, there is no evidence in literature if mad honey is exported from Nepal. This form of poisoning from honey has been known since 401 BC; an ancient Greek philosopher Xenophon of Athens refers to soldiers being poisoned by honey in his book 'Anabasis' (Gunduz *et al*., 2007). Since cases of mild poisoning are well known to the local inhabitants, they do not generally visit health institutions when affected. Well-known toxic effects of honey poisoning include bradycardia, cardiac arrhythmia, hypo-tension, nausea, vomiting, sweating, salivation, dizziness, weakness, and loss of consciousness, fainting, blurred vision, chills, cyanosis (a bluish discoloration of the skin due to poor circulation of the blood) and convulsions (Gunduz *et al*., 2007). However, patients with severe symptoms do go to hospital, and patients whose heartbeat and vital signs improve are discharged after three to six hours. Until 2006, more than 120 cases resulting from ingestion of this honey have been reported (Yilmaz *et al*., 2006).Mad honey has the potential to cause death if left untreated, although no fatal case has been reported in the literature. Complete recovery after admission to hospital is normally the rule, because the resulting hypotension usually responds to appropriate fluids, and bradycardia and conduction defects usually respond to atropine treatment.

CONCLUSION

Mad honey is used less as a food and more as a hallucinogen or recreational drug. In some cases, it is also used as traditional medicine, especially by the local mountain people involved in honey hunting. It is believed in some communities that this type of honey promotes general well-being, including the treatment of gastric and coronary artery diseases, cold, and viral infection, as an analgesic, and as a sexual stimulant. But, many analyses reported by the literature prove that it can be harmful to the body as well. The effect of the honey, either medicinal or poisonous largely depends on the dose in which it is consumed. Consuming more than a teaspoon of the mad honey at a time can cause dizziness, cloudy vision, nausea, weakness, vomiting, fainting, sweating, hypotension and bradycardia. The poisonous property of the wild honey comes from presence of grayanotoxins collected by bees from the flowers of. Awareness among the consumers is needed about the toxicity of the wild honey to avoid morbidity and any fatal cases. Nepal needs to introduce grayanotoxin detection and isolation facilities as well as grayanotoxin free certification system to resume export of honey to South Korea and to promote honey export to international markets.

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POLICY FRAMEWORK FOR CLIMATE-INDUCED DISASTER RISK MANAGEMENT IN AGRICULTURE SECTOR OF NEPAL

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ABSTRACT

More than 60% of the cropped area depends on rains brought about by the summer monsoon (80% of the total rainfall), which is a major cropping season in the country. Climate risks brought about by weather events as late onset of rains, long dry spells during the monsoon season, early withdrawal of monsoon, heavy rainfall episodes, and deficient winter rainfall, cold waves in December-January and hailstorms and thunderstorms during March-May affect agriculture operations. This paper review the literature regarding climate induced DRM and develop policy framework for agriculture sector. Nepal's plan, policy, strategy and program do not consider DRM too much and mostly engaged in response and recovery ignoring preparedness. Only 4% of the budget spent on preparedness and 96% of the budget spent on response and recovery (MOHA, 2018). Additionally, government investment for agriculture is only around 3-4% of the total budgetary resources. Agriculture production could increase if climate induced risks are managed effectively using currently available tools and practices such as integrating early forecasting for the management of agricultural operations.

Key Words: Agriculture, climate change, disasters, economy, production

BACKGROUND

It is now widely acknowledged that climate change can further alter the observed climate mean, cause changes in the nature of extremes (i.e., severity, frequency, spread, duration and timing) and present possible natural disasters. The resulting climate risks could look like current climate variability patterns, but with higher amplitude variations. Human experiences in dealing with extreme climate events may provide guidance for dealing with the uncertainties associated with climate change-related risks. This means that the promotion of resilient development and the building of capacity for institutions and systems to manage current climate extremes are critical for these institutions and systems to cope with natural disasters. Natural Disaster has the potential to impair conflict, displace people, and destroy livelihoods, set-back development and the fight against poverty for millions of people across the world. It is estimated that over 20 million people in the Mekong Delta and 20 million in Bangladesh could be forced to move as their homes are affected by saltwater incursion from rising sea levels (Nicholls, 2004).As climate change creates new risks, better analysis and adaptation is needed to understand and minimize a new level of uncertainty.

In order to plan for climate induced disasters, we need to understand how climate change will impact on economies, livelihoods and development. We need to understand how likely changes in

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temperature, precipitation, as well as the frequency and magnitude of future extreme weather will affect any sector, including agriculture, water-use, human and animal health and the biodiversity of wetlands. Like the threat from many disasters, there is still time to prepare for the worst impacts of it in developing countries if we expand our understanding right now.

Agricultural growth and development was appeared to be sluggish in the past. Among the cereals, paddy covers about 31% of the total cultivated area and accounts for 7.5% to the national GDP, 56% of total cereal outputs. Although agriculture's contribution to the country's GDP has been declining over time (Table 1), the sector remains to be the largest, sustaining at least 15 million people. Over the past decades, however, the country has been experiencing food shortages due to severe weather conditions like drought, floods, landslides, and hailstorms among others. Food grain trends in the past decades show positive growth in production except the years 2005-2007 and 2014, when there was food shortage mainly due to weather conditions. In general, climate variability is one of the major causes of inconsistent crop yields and food production in the country.

Table 1. Contribution of Agriculture sector in Nepalese economy

Particulars	Share of agriculture (%)				
	1980-81	1990-91	2000-01	2010-11	2016-17
GDP	57.40	48.80	40.10	36.54	29.37
Total households	84.90	82.20	84.08	70.63	70.63
Total population	85.70	87.90	85.80	74	63

Sources: Economic Survey, MOF, 2015/16; CBS, 2016/2017

Another reason for low productivity in agriculture is landholdings, distribution, tenure and access. The average size of landholding is about 0.68 ha, and land is often fragmented in scattered parcels. About 53% of the farmers even have less than 0.5 ha, and share only 20% of the total land, 20% of the farmers have more than 1 ha land (CBS 2015). Per capita arable land availability (0.082 ha/person) is less than half of the world's average (0.7 ha/person) and hampers commercialization and the realization of economies of scale for small-sized farms by constraining farm mechanization. Additionally, many of the areas lack adequate road infrastructure and transport that provide linkages to markets. The weak small farm holding sizes and the lack of access are major constraints in improving the living conditions of farmers via mechanization and modernization. For this, the government is advocating for land pooling or amalgamation to introduce mechanization and commercialization of the sector to increase investments and to connect production to markets. The new concept of pocket, block, zone and super zone were started to make the best utilization of available land resources.

The slow growth of the agriculture sector in recent years has been associated with farming practices highly dependent on weather conditions, insufficient irrigation facilities, unavailability of agricultural inputs (particularly seed and fertilizers), and an increasing trend of land fallowing and abandonment. Government efforts to boost the agriculture based economy have focused on easing dependency on weather conditions, increasing productivity and diversifying the range of crops for local consumption. Solutions include the use of machines, advanced irrigation systems, chemical and organic fertilizers and improved seed varieties as well as the provision of access to credit and technical advice.

Urban areas in low and middle-income countries like Nepal have more than a third of the world's total population, nearly three-quarters of its urban population and most of its large cities. They contain most of the economic activities in these nations and most of the new jobs created over the last few decades. They are also likely to house most of the world's growth in population in the next 10–20 years (UN, 2006). In regard to climate change, they already house a large proportion of the population and the economic activities most at risk from extreme weather events and sea-level rise and this proportion is increasing.

OBJECTIVE

The main objective is to review the policy and action plan related to climate induced disaster and way forward to contribute to the economy.

METHODOLOGY

This paper is based on literature review and secondary sources. Available literatures focused on climate induced disaster and impact on agriculture were reviewed. The disaster risk reduction and management act-2017, National Strategy for Disaster Risk Management (NSDRM)-2009, Sendai Framework for Disaster Risk Reduction 2015-2030, National Disaster Response Framework (NDRF) 2013, climate change policy 2010, National Adaptation Program of Action (NAPA)-2010, National Adaptation Plan (NAP), and National climate change impact survey-2016 were reviewed. The main data sources are national planning commission, ministry of agricultural development, Ministry of population and environment, central bureau of statistics, ministry of livestock development, ministry of finance, ministry of home affairs, FAO, ICIMOD, UNDP and other development partners. This paper analyzed:

- Climate analysis, which includes assessments of historical, current and projected climate data, trends and risks;
- Assessment of institutional and policy structure and capacity to address governance, policy and capacity deficits through stakeholder analysis, institutional mapping and research;
- Review economic loss due to disaster from agriculture sector

RESULT AND DISCUSSION

This section includes some qualitative and quantitative information.

1. GENERAL INFORMATIONAND FACT ABOUT AGRICULTURE AND DISASTER

The agriculture sector is extremely exposed to the impacts of natural disasters and climate change. The most frequent are geological and climate-related disasters like floods, landslides, avalanches and Glacial Lake Outburst Flood (GLOF), storms, earthquakes and wildfire. Since 2005, the natural disasters affected about 7.8 million people and caused over 10,000 deaths. Particularly severe was the impact of Gorkha earthquake in 2015, when the total of 8,870 people were confirmed dead, the total damages and losses accounted to US$ 8.81 billion, out of which the total damages and losses in agriculture sector amount to about US$ 1.1 billion. Apart from extreme events, Nepal is vulnerable to slow-onset hazards (droughts, temperature rise). According to global vulnerability index (ND-GAIN) it ranks as the 54th most vulnerable country. In the climate change vulnerability index Nepal is ranked as the 4th most climate vulnerable country in the world (World Bank 2011). The Climate

Public Expenditure and Institutional Review (CPEIR) found that annual expenditure on all climate change related activities constitutes approximately 2% of GDP and round 3% of total government expenditure. In case of natural disasters, around 4% budget is spent for preparedness and remaining 96% will be spent on rescue and response.

Nepal's GHG emissions are estimated at roughly 40 megatons of CO2 equivalent (CO2eq) per year, including emissions from Land Use Change and Forestry (LUCF). Per capita annual GHG emissions, including LUCF, are less than a quarter of the world average, at 1.52 tons of CO2eq. More than half of the country's total emissions come from the agricultural sector (52%). Of all agricultural emissions, 60% are attributable to enteric fermentation and manure management from livestock production. Meanwhile, approximately 24% of agricultural emissions result from cropping practices including rice cultivation, crop residues, cultivation of organic soils, burning of crop residues, and the use of synthetic fertilizers. Promotion of practices and technologies geared towards improved efficiency in animal production (e.g., balanced animal nutrition, reduction of disease incidence, and genetic improvement) can, therefore, be crucial for GHG reduction in Nepal. Recent trends in cropland intensification suggest an accelerated increase in agricultural emissions unless adequate measures to apply and manage agricultural inputs (such as precise fertilizer management techniques) are implemented (CSA, 2017).

2. REVIEW OF KEY RELEVANT POLICY DOCUMENTS

NSDRM 2009 provided the basis for a shift from a reactive and relief guided approach to one of disaster risk reduction, preparedness and effective response. The NSDRM envisaged a disaster-resilient Nepal as called for in the HFA-2005-2015.

Currently, the Nepal Government is preparing the Strategic Action Plan in line with the Sendai Framework for DRR 2015-2030, considering the lessons learned and gaps identified through the implementation of the NSDRM 2009, 2015 earthquake response, initiatives on CCA and SDGs.

The bills on DRRM Act 2017 approved, replacing the DR Act of 1982. This is the milestone to prepare and respond to disasters with new concept and changes the names and structures throughout the country. NDRF-2013 which has endorses the cluster system in Nepal and also clarifies the roles and responsibilities of different line ministries and development partners.

3. CURRENT CLIMATE VARIABILITY AND CLIMATE EXTREMES

For the most part, climate variability is driven by changes in the summer monsoon originating from the Bay of Bengal, winter precipitation by westerly disturbances coming from the Mediterranean Sea, and by thunder storms. Finally, the duration of the monsoon is found to be longer than normal with increasing trends in recent years, especially after 1990. These late onsets coupled with late withdrawals and longer durations suggest a general shift in monsoon activity.

Floods in Nepal are usually provoked by high intensity rainfall, continuous rainfall for several days, glacial lake outburst and landslide dam outburst. The middle mountain region of Nepal has experienced flash floods in the past, and the Terai has been affected by riverine floods more often than other areas. This is because high sediment loads from the mountain region are carried by the rivers and deposited in the plain areas of Terai where the river bed level rises resulting in the water outflanking the banks. For example, Seti floods in Kaski district occurred in the month of May, 2012 triggered by an avalanche/cloudburst. Gullies, badlands and landslides are responsible for more than 90% of the losses in cultivated lands (Kienholz et al, 1983). Already, an estimated 10 tons/ha of soil is eroded every year during the rainy season (Poudyal-Chhetri and Bhattarai, 2001). Droughts in parts of the country typically occur from the end of March through June, that is, until the arrival of the monsoon season. The results showed that the districts of hill and mountain ecological zone of Far and Mid-Western Development Region, and Terai ecological zone of Eastern Development Region are prone to drought risks. Large amount of rainfall within a short period causes flash floods, massive landslides and soil erosion in the hilly and mountainous regions, as well as sedimentation and inundation in the plain areas. The maximum 24-hour extreme rainfall recorded was in Hariharpur Gadi, Sindhuli (482.2 mm) on 20 July 1993 (MOPE, 2004).

4. OBSERVABLE CHANGES IN CLIMATE VARIABLES

Records of the last 30 years indicate that temperatures in Nepal are increasing, and the warming seems to be consistent and continuous after the mid-1970s. Long-term (current and previous decades) hydrological and meteorological data from the DHM indicate consistent warming and rise in maximum temperatures at an annual rate of 0.04–0.060C. Analysis of the annual precipitation of 166 stations for the period 1976 to 2015 showed an increasing trend in annual precipitation except for the far-western and northern parts of western, central and eastern Nepal where there is a declining trend. A general decline in pre-monsoon precipitation is also seen in far- and mid-western Nepal despite a general trend of increasing pre-monsoon precipitation in the rest of the country (Practical Action Nepal, 2009). Winter precipitation shows an overall increasing trend in Nepal. Each year, about 300 people in Nepal die due to climate-induced disasters. In addition, an estimated 80% of the total economic loss of disasters since 1970 (i.e., about USD 1,036 million) is due to climate-induced disasters (MoHA, 2016).

5. TEMPERATURE AND PRECIPITATION PROJECTION FOR NEPAL

Finally, a more recent study by NCVST (2009), which used General and Regional Circulation Models projects the mean annual temperature to increase by 1.40C by 2030, 2.80C by 2060 and 4.70C by 2090. The outputs suggest that extremely hot days (the hottest 5% of days in the period 1970-1999) are projected to increase by up to 55% by 2060 and 70% by 2090. In the same way, extremely hot nights (the hottest 5% of nights in the period 1970-1999) are projected to increase by up to 77% by 2060 and 93% by 2090. Meanwhile, GCMs project a wide range of precipitation changes, especially in the monsoon: -40 to +143% by 2030, increasing to -52 to 135% by 2090 (Table 2). The NCVST (2009) projections show no precipitation change in western and up to 5-10% increase in eastern Nepal for winter.

Table 2. Precipitation projection for Nepal

Year	Annual mean rainfall		Monsoon rainfall	
	Multi-model mean	Range	Multi-model mean	Range
2030	0%	-34 to 22%	2%	-40 to 143%
2060	4%	-36 to 67%	7%	-40 to 143%
2090	8%	-43 to 80%	16%	-52 to 135%

Source: NCVST, 2009

6. DISASTER IMPACTS

From 1971 to 2013, more than 32,758 people were killed and another 6.9 million were affected in disaster events of all types (Table 3). Direct losses of more than USD 40 billion were reported.

Table3. Disaster losses in Nepal (1971 -2013)

Year	Death	Injured	Missing	Houses Destroyed	Damages in crops Ha.	Lost Cattle	Losses $Local
1971	311	57	0	131	500	1335	861750
1972	173	88	37	771	397	340	4709610
1973	214	317	9	1957	1404	709	3709000
1974	507	725	43	2615	17347	1431	11580753
1975	263	133	38	2051	1292.34	723	6146670
1976	250	93	35	4957	30404	1714	43056099
1977	162	245	4	1347	12876.85	299	2807313
1978	471	90	1	3132	345	959	13379700
1979	640	114	0	2061	803.45	695	17632244
1980	423	506	67	14348	16818	10881	10494713
1981	258	434	201	1246	9537	687	6551515
1982	683	24	19	1039	1614.28	6894	52639700
1983	467	122	15	1384	1448.02	399	30643775
1984	1091	611	24	2568	5429.43	2892	41812394
1985	229	77	7	1475	26.977	1067	39516710
1986	289	34	0	1160	222.65	392	257369000
1987	122	68	0	1041	2494.24	804	42702500
1988	1291	8167	2	23035	947.8	1446	27204279
1989	352	1419	5	4813	7898	669	128459890
1990	512	4107	35	1209	1791	91	22616434
1991	1097	179	26	1392	243	100	88142382
1992	998	29	63	6225	77993	442	191258832
1993	1804	303	81	20061	90044.756	25165	1133401021
1994	1177	1255	46	3175	158970.74	766	97607862
1995	1158	1484	35	9685	23647.42	2409	2130794788
1996	1147	1579	98	19638	6849	2995	395301461
1997	1331	944	4	4549	80666.15	26416	489260411
1998	1154	304	16	15978	3975.36	1035	383162560
1999	1409	422	43	4046	3023.08	1101	565015746.5
2000	708	342	19	3038	36579.8	1125	742961747
2001	1902	3465	80	6308	51920.363	28672	1509257741
2002	874	12082	104	14059	12586.066	4593	2842002280

Year	Death	Injured	Missing	Houses Destroyed	Damages in crops Ha.	Lost Cattle	Losses $Local
2003	971	3438	86	1974	72626.94	2395	512862500
2004	1105	224	60	1641	37480	101993	1406674920
2005	333	165	100	1449	15.81	1484	142590000
2006	599	5859	101	1927	72745.51	1297	487352000
2007	637	4694	92	9456	5774.79	499566	633227700
2008	936	1267	125	16026	89467.522	8788	2039139202
2009	1260	1305	140	3761	38901.63	7782	947036820
2010	1002	581	142	5330	11160.8289	2519	1736135875
2011	977	1040	185	7490	31105.479	1321	2155133900
2012	845	671	75	3594	13058.76	10772	16772189386
2013	626	532	111	2518	2172.45	1302	2321601000
Total	32758	59595	2374	235660	1034605.492	768465	40486004184

Source: MoHA and DPNeT, 2016

6.1 Climate Sensitivity

Intra-seasonal variation analysis revealed that from 2000 to 2009, an average 70,000 ha of paddy crop area is affected by droughts annually and in extreme years like 2006, the affected area goes up to 270,000 ha. On the other hand, more widespread droughts occur once every five to seven years. Table 4 presents the outcomes of a climate sensitivity analysis for five major crops planted in various districts. For paddy, the coefficient of variation (CV) for the majority of districts (58%) is 10-15%. This means that yields vary between 10-15% from the mean. Maize is more variable with more districts (i.e., 46 and 32%) having yields that vary between 10–15 and 15–20%. The case is relatively similar for wheat and barley where yields for the majority of districts fall between the 10-20% range. On the other hand, millet is more resilient with most districts (62 %) having less than 10% CV. These results indicate that some crop yields are indeed more variable than others in particular districts and less in other districts.

Table 4. Variability of district-level average crop yields

District level CV in mean yield	Paddy	Maize	Millet	Wheat	Barley	Total
<10%	23%	15%	62%	4%	26%	26%
[10% to 15%]	58%	46%	30%	30%	40%	41%
[15% to 20%]	13%	32%	6%	51%	31%	26%
> 20%	6%	6%	3%	15%	3%	7%
Total Districts	100%	100%	100%	100%	100%	100%

Source: World Bank, 2009

Table 5 builds on the data from Table 4 and provides specific values of exposures for eight different crops in three different regions, including a total for the country. The total value of crops exposed to climate sensitivity is around NRS 105 billion and 800 million (US$ 1.6 billion).

Table 5. Total values at risk for 100% yield coverage level (NRS. Million)

Crops	Mount.	% of Values	Hills	% of Values	Terai	% of Values	Total Nepal	% of Values
Paddy	1,358	1.3%	10,800	10.2%	32,394	30.6%	44,551	42.1%
Maize	1,566	1.5%	12,344	11.7%	3,503	3.3%	17,413	16.5%
Millet	509	0.5%	1,973	1.9%	76	0.1%	2,558	2.4%
Wheat	870	0.8%	5,213	4.9%	10,610	10.0%	16,693	15.8%
Barley	66	0.1%	23	0.0%	0	0.0%	89	0.1%
Oilseed	16	0.0%	316	0.3%	1,644	1.6%	1,977	1.9%
Potato	2,217	2.1%	7,383	7.0%	8,863	8.4%	18,463	17.5%
Sugarcane	0	0.0%	0	0.0%	3,831	3.6%	3,831	3.6%
Total	6,603	6.2%	38,052	36.0%	61,145	57.8%	105,800	100.0%

Source: World Bank, 2009

Data showed that climate risks could cost the country a total loss of 42.1% of the paddy crop followed by potatoes at 17.5%, maize and wheat at 16.5% and 15.8% respectively. Delayed onset of monsoon has also been affecting crop production while some harvesting seasons have been badly hit by the heavy rainfall and hailstorm. Since paddy is the most climate sensitive crop, analysis was made to assess the impact of intra-seasonal variation on paddy for the years 2001–2010. Analysis estimates the total risk from weather exposure at USD 753 million, about 30% of which is due to extreme events during the years 2006 and 2009, which resulted in as much as USD 229 and USD 125 million in production loss respectively.

6.2 Impact of climate change on crop yield

An analysis using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT)5 [Robinson et al., 2015] was carried out for the selected key production systems in Nepal, analyzing impacts of climate change over the period of 2020 – 2050, on net trade, yield and area (for crops).

The results show that CC has mixed effects on agricultural production, potentially contributing to the increase in yields and land area for some crops, and decreases for others16. For example, climate change is likely to increase rice, vegetable and sugarcane [crop] areas, while reducing the area of maize, wheat, lentil and potato. In terms of yield levels, maize, potato, sugarcane and lentil are likely to be most negatively affected by CC, as yields in 2050 are projected to be lower by -16.1%, -8.9%, -8.0% and -4.9% under a CC scenario, as compared to none climate change (NoCC). Also rice and vegetable yields are expected to be lower under CC than under NoCC, yet the projected differences are comparably small (-0.4% and -0.1%, respectively). Wheat, on the contrary, is likely

5 IMPACT, developed by the International Food Policy Research Institute, is a partial equilibrium model using a system of linear and non-linear equations designed to approximate supply and demand relationships at a global scale. This study used the standard IMPACT model version 3.2, less the IMPACT-Water module. The tool uses the General Algebraic Modeling System (GAMS) program to solve a system of supply and demand equations for equilibrium world prices for commodities. The tool generates results for agricultural yields, area, production, consumption, prices and trade, as well as indicators of food security.

to benefit from climate change, as by 2050 the yield levels are shown to be 3.4% higher under CC than NoCC (CSA, 2017).

7. MANAGEMENT

Most of the Climate Risk Management (CRM) initiatives in Nepal focus on managing extreme events, and prioritize rapid-onset events. Policies and institutions related to risk management are also biased towards these hazards while other risks such as droughts, intra-seasonal variations in rainfall and temperature fluctuations have been largely ignored. To date, there are three distinct frameworks related to risk management in Nepal: i) development planning, ii) disaster management, and iii) climate change adaptation.

7.1 Development Planning

The NPC leads the development planning process with a mandate to coordinate national development plan preparation with the participation of all the sectors. The Three year plan (TYP) also highlights key areas like agriculture and food security, forestry and watershed management, and hydropower and alternative energy to manage some of the challenges from climate change. The GoN has also brought out the Climate Change Budget Code and CC Resilient planning tools.

7.2 Disaster Risk Management Framework

The Natural Calamity Relief Act of 1982 was just replaced by Disaster Risk and Management Act 2017 (2074). This act provides for the establishment of national council (NC) for the disaster risk reduction and management at central level chaired by the Prime minister. One executive committee will be formed headed by the home minister to assist council to prepare national disaster policy and programs and also implement the plan and programs approved by the council. One expert committee can be formed by the home ministry with five members from different disciplines. Beside this, for the effective management and implementation of disaster management activities and programs, one national disaster risk reduction and management authority will be formed under home ministry. There is the separate provincial disaster management committee (PDMC) lead by chief minister, district disaster management committee (DDMC) lead by chief district officer (CDO) and local disaster management committee (LDMC) lead by chairperson of the local government (Mayor). This act focused on pre and post disaster activities like preparedness, rescue, response and rehabilitation rather than focusing only on relief and rescue like previous act. A central level fund namely disaster management fund will be maintained.

The NSDRM is the key document to achieve the goal of disaster resilient Nepal by providing guidance for improving the policy and legal environment, and by prioritizing the strategic interventions. The NSDRM has led to a paradigm shift in disaster risk management from a reactive intervention in the form of relief to a proactive approach of mitigation.

7.3 Climate Change Framework

The country's National Adaptation Program of Action (NAPA)-2010, guides adaptation actions across various sectors. Similarly, the Climate Change Policy-2011 is used to identify overall climate change priorities. Based on these, a National Climate Change Strategy is under preparation at the Ministry of Environment to guide climate change adaptation projects and actions. For the agriculture sector, priority programs include integrated management of agriculture, water management, improved systems, livelihood diversification, and access to agriculture development services, identification of potential drought areas, early warning and forecasting for adverse temperature, floods and other hazards impacting the sector. As for institutional set-up, the Climate Change Council is the highest advisory body providing high level policy and strategic inputs, as well as coordinating financial and technical support for climate change policies and programs.

8. CLIMATE RISK ASSESSMENT

A policy and institutional mechanism needs to be established to facilitate continuous assessment of risk factors that impact agriculture. Such system would improve decision-making through appropriate anticipatory response strategies. The analyses need to identify potential risks and possible response options for managing risks in the sector. One crucial aspect of the above-mentioned process is facilitating the linkages among key stakeholders – MOAD, MoF, MoHA, NPC, DHM, Fisheries, Animal Husbandry, Irrigation – and support institutions such as agriculture insurance and markets.

9. INFORMATION MANAGEMENT

A conservative estimate of the value of weather information (in minimizing climate risks and maximizing potential gains) for the agricultural sector is estimated at USD 601 million per annum. For this to happen, a dedicated institutional system needs to be built within MOAD. The establishment and institutionalization of a user-relevant climate information system involves:

- Climate information should be interpreted in terms of sector-specific thresholds, jointly determined by institutional users and communities.
- Climate information is applied in planning and decision-making, cognizant of the risks due to uncertainties in the information.
- Appreciation of the economic and social benefits derived from investing in an end-to-end climate risk management system (e.g., time, human resources, and finances) shall lead to the adoption of the CRM framework and institutionalization of the CRM system.

CONCLUSION

The physical and economical loss in human lives and livelihood as well in agriculture which is our culture is increasing day by day due to disasters. The government approach to handle the disaster was reactive and mostly focus on rescue, relief and recovery and new DRRM act, 2017 approved focusing preparedness as well. This approach should be implemented quickly to minimize the risk induced by disaster in future and protect our nature and natural resources. Till date, total budget spent for climate change is altogether around less than 1%, out of total budget allocated. The pattern of budget expenditure is around 96% to adaptations and only 4% for preparedness. This volume should be fifty fifty and guided by the recent policies.

To support effective climate risk reduction functions in agriculture the following pre-requisites are essential:

i. Functional agriculture risk information system;
ii. Investments in agriculture infrastructure – irrigation systems and services – including extension services;

iii. Contingency crop planning capacitated with logistics support, such as provision of alternate seeds and fertilizers, and;
iv. Mechanism for delivery of information and services through capacity building of wards of different rural, municipality, metropolitan and provinces. It is essential to involve local government institutions since DOA would be unable to meet requirements in all local governments on its own.

Building a CRM system would help reduce climate risks in agriculture, and address a huge loss of about USD 270-360 million each year due to weather risks and impacts on major crops like paddy, maize, millet and wheat. A policy shift from low investment of 6% on agriculture to at least 20 % can help build research capacities and systems for agriculture extension services, information management, and identification of response options, among others.

A conscious investment of resources would help not only generate better returns but also address the pressing issue of migration from rural areas by providing better income and employment opportunities.

The new DRRM would be a key asset to address the all aspirations of disasters before and after in the coming days.

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EFFECT OF ORGANIC NUTRIENT SOURCES ON UPLAND RICE PRODUCTION AND SOIL PROPERTIES

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ABSTRACT

Improvement and maintenance of a good status of organic matter in soil through regular supply of organic manures is a pre-requisite for efficient recycling of nutrients. An experiment was conducted in the research block of agronomy farm of Institute of Agriculture and Animal Science (IAAS) Rampur, Chitwan from April to November, 2009 in order to evaluate the response of upland rice (IR-55435-5 to different sources of organic manures and soil properties. Rice was cultivated using seven types of organic manuresi) Farmyard manure (FYM) @ 14 t ha^{-1}, ii) Decomposed biogas effluent @ 9 t ha^{-1}, iii)Fresh biogas effluent @ 8 t ha^{-1}, iv) Banmara compost (Compost of 1 part biogas effluent + 1 part banmara) @ 6 t ha^{-1}, v) Ashok dry leaves compost (Compost of 1 part biogas effluent + 1 part ashok dry leaves) @ 11 t ha^{-1}, vi) Rice husk compost (Compost of 1 part biogas effluent + 1 part rice husk) @ 15 t ha^{-1}, vii) Chemical fertilizer (NPK @ 100:60:40 kg ha^{-1}). Four replications of the treatments were laid out in Randomized Complete Block Design (RCBD) with plot size of 12 m^2 (4 m x 3 m).Result revealed that the grain yield of upland rice was 1.63 t ha^{-1} (Ashok dry leaves compost), 1.67 (Banmara compost) 1.675 t ha^{-1} (Farmyard manure), 1.71 t ha^{-1} (Rice husk compost), 2.05t ha^{-1} (Decomposed biogas effluent), 2.18 t ha^{-1} (Fresh biogas effluent) and 2.33 t ha^{-1}(Chemical fertilizer) with the average grain yield1.89 t ha^{-1}.Also the highest soil organic matter content (2.716 %) was determined in fresh biogas effluent applied plots which was significantly (p= 0.05) higher than the rest of the treatments and was statistically at par with decomposed biogas effluent (2.630%) applied plots. Thus, it is concluded that biogas effluent is the best source of nutrient among the organic manures and sound alternative to inorganic fertilizer.

Key words: Ashok, compost, FYM, organic, rice husk,

INTRODUCTION

Organic farming has been described as a complex system (Brumfield *et al.*, 2000) of agricultural production where productivity improves with increasing years (Lockeretz *et al.*, 1981). Organic manures are the core of organic farming which supply most of the nutrients and improve the overall properties of the soil. They help improve the soil physical and chemical properties (Biswas and Khosla, 1971) through improvement of soil organic carbon status and the supplement of primary and secondary nutrients (Badanur *et al.*, 1990) and micronutrients in available forms (Kher, 1933). Several experimental transition studies have reported initially lower yields in organic farming, followed by yields similar to conventional (chemical based) production (MacRae *et al.*, 1990). Improvement and maintenance of a good status of organic matter in soil through regular supply of organic manures is a pre-requisite for efficient recycling of nutrients. Farmers use various types of organic manures and fertilizers to maintain soil fertility and increase productivity. Biogas effluent is

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one of them, which is used as organic fertilizer to rejuvenate soils since it is a rich source of both plant nutrients and organic matter (Islam, 2006). The use of biogas effluent solely or the compost of locally available materials withit can be a good practice to supply nutrients in upland conditions. The compost of rice husk prepared with poultry manures is common among the farmers as an organic fertilizer that plays a vital role not only in improving soil physical condition but also in improving the plant nutrients. Research has shown that compost made from rice husk used under different irrigation intervals gave good rice stand, better grain yield and higher water use efficiency (Abo-Soliman *et al.,* 1990). Materials such as *banmara* (*Eupatorium odoratum*) weeds and dry leaves of other common trees like *Ashok* (*Polyalthialon gifolia*) can also be used for preparing compost and application of such compost improves the crop performance and soil properties. Banmara is a common weed of waste and marginal pasturelands in Nepal. The luxuriant vegetative growth of this weed coupled with the spreading root systems extract large quantities of nutrients from the soil, and may act as a nutrient pump (Obatolu and Agboola, 1993). These materials are locally available, easy to use, cheap, and compatible farmer's practice and with long term sustainability and eco-friendly. The low yield of upland rice is because of its production being limited tolow harvest index varieties; infertile soils and heavy weed infestation; increased cropping intensity; insufficient and irregular rainfall; and lack of improved production technologies and associated high yielding cultivars (George, 2001). Since upland rice is grown mostly by the resource poor farmers without an access to the modern inputs (chemical fertilizers), emphasis should be given to increase the production of this crop by the use of organic manures. Rather, the adoption of organic farming using locally available sources for crop nutrient management seems imperative. This fact illustrates the need of research on the response of the crops to locally available materials, enriched by composting with biogas effluent as the source of nutrient supplement. To address the issue of using various organic manures (biogas effluent and its compost with other organic materials) in upland rice, a research was designed to assess the residual effect of different organic manures and to evaluate the response of upland rice to biogas based organic manures *vis-à-vis* farm yard manure and chemical fertilizers

MATERIALS AND METHODS

EXPERIMENTAL SITE

The experiment was conducted in order to evaluate the response of upland rice to different source of organic manures in the research block of agronomy farm of Institute of Agriculture and Animal Science (IAAS) Rampur, Chitwan from April to November, 2009. This site is 256 meter above mean sea level at 27^{o} 37' North latitude and 84^{o} 25' East longitudes and was 9.8 km south-west from Bharatpur, headquarter of Chitwan district.

PHYSICO-CHEMICAL PROPERTIES OF THE SOIL OF EXPERIMENTAL SITE

Composite soil sample from the experimental field was randomly taken from a depth of 0-15 cm using tube auger. The soil samples were evaluated for total nitrogen and available P and K, soil texture, total organic carbon and soil pH using standard method. The total nitrogen was determined by kjeldhal distillation unit (Jackwson, 1967), available phosphorus by spectrophotometer (Olsen *et al.*, 1954) and available potassium by ammonium acetate method (Black, 1965). Organic matter was determined by Walkey and Black method (1934). Soil was determined in pH (1:2 soil and water suspensions) by Beckman Glass Electrode pH meter (Wright, 1939) and soil texture by hydrometer method.

Table 1.Physico-chemical properties of the soil of the experimental plots at IAAS, Rampur, Chitwan, Nepal

Physical Properties	Average content	Scale	Chemical properties	Average content	Scale
Sand (%)	75.8		Soil pH	6	Acidic
Silt (%)	18.2		Soil organic matter (%)	1.87	Low
Clay (%)	6.0		Total nitrogen (%)	0.09	Low
Texture/Rating		Sandy loam	Available phosphorus (kg ha^{-1})	12.06	Low
			Available potassium (kg ha^{-1})	24.84	Low

The average soil pH of the experimental field was slightly acidic (pH 6). The nitrogen in the field represented low (Khatri Chhetri, 1991), phosphorus and potassium in lower range, and organic matter of soil (Jaishy, 2000) indicated the low soil fertility status (table 1).

The highest rainfall was recorded during July (753.5 mm). The relative humidity ranged from 57.5 % in April to 98.8 % in December with mean maximum temperature (from 23.4°C to 37.41°C) and mean minimum (10.2°C to 26.5°C).

DETAILS OF EXPERIMENT

Six different types of organic manures prepared with locally available materials in the IAAS farm, were used in upland rice to supply the nitrogen equivalent to 100 kg N ha^{-1}. Urea, DAP and muriate of potash, were used to evaluate comparative effects of organic manures and chemical fertilizers. Upland rice variety used in the experiment was IR-55435-5 as this variety was the very popular, also known as the variety of resource poor farmers, highly adopted variety in mid-hill with average productivity.

PREPARATION OF COMPOST

Different types of compost namely; banmara compost, ashok dry leaves compost, and rice husk compost were prepared by mixing locally available materials with biogas effluent. The compost was prepared by pit method. Pits size of 1 m x 0.75 m x 0.5m were dug near the experimental field. After digging the pit, biogas effluent and composting material (1:1 ratio) were mixed layer wise. The compost was left in the pit for two and half months to allow complete decomposition. The turning of compost was done two times during decomposition process. The followings were the different types of compost.

Banmara compost: Banmara compost was prepared by mixing 1 part of biogas effluent with 1 part of banmara (Biogas effluent + banmara) on weight basis.

Ashok (*Polyalthia longifolia*) dry leaves compost: The compost prepared by mixing 1 part of biogas effluent with 1 part of ashok dry leaves (Biogas effluent + ashok dry leaves) in a compost pit.

Rice husk compost: Mixing 1 part of biogas effluent with 1 part of rice husk (Biogas effluent + rice husk), rice husk compost was prepared.

Farmyard manure (FYM): FYM, prepared by the farmers on their traditional way, heap method, was used as one of the sources of nutrient.

Biogas effluent: Biogas effluent was collected from the farmers having biogas plant.

Analysis of manures: Three samples of compost were taken from top, medium, and lower layers and was made a composite sample then analyzed on the dry weight basis (table 2).

Table 2. Nutrient contents of different types of compost used in the research at IAAS, Rampur, Chitwan, Nepal

S.N.	Description	N%	P%	K%
1	Farmyard manure	0.71	0.35	0.99
2	Decomposed biogas effluent	1.11	0.22	0.35
3	Fresh biogas effluent	1.20	0.40	0.65
4	Banmara compost	1.71	0.42	0.65
5	Ashok dry leaves compost	0.93	0.31	0.60
6	Rice husk compost	0.66	0.21	0.35

TREATMENT AND EXPERIMENTAL DETAILS

The experimental field was laid out in Randomized Complete Block Design (RCBD) with four replications and seven treatments with plot size of 12 m2 (4 m x 3 m). There was a bund of 0.5 m width between two experimental plots and each replication was separated by bund of 1 m width. Plant geometry was maintained with 25 cm between rows and seedling was done continuously. There were 15 rows of 3 m length in each plot.

There were seven treatments applied in the research. Seven different sources of plant nutrients including chemical fertilizers was used as nutrient sources for nutrition of upland rice. The quantity of manure was applied to supply 100 kg N ha^{-1}.

Table 3. Details of the treatments for upland rice experiments at IAAS, Rampur, Chitwan, Nepal

S.N.	Treatments Combination	Symbol
1	Farmyard manure (FYM) @ 14 t ha^{-1}	T1
2	Decomposed biogas effluent @ 9 t ha^{-1}	T2
3	Fresh biogas effluent @ 8 t ha^{-1}	T3
4	Banmara compost (Compost of 1 part biogas effluent + 1 part banmara)@ 6 t ha^{-1}	T4
5	Ashok dry leaves compost (Compost of 1 part biogas effluent + 1 part ashok dry leaves) @ 11 t ha^{-1}	T5
6	Rice husk compost (Compost of 1 part biogas effluent + 1 part rice husk) @ 15 t ha^{-1}	T6
7	Chemical fertilizer (NPK @ 100:60:40 kg ha^{-1})	T7

CULTIVATION PRACTICES

The experimental plots were prepared after manual digging of 2-3 times; weeds were removed, and organic manures were added according to the treatments. Twenty eight plots were prepared according to the experimental design. After field preparation, IR-55435-5 variety of rice was seeded continuously in the line by using hand drilling method on 27th June, 2009 in all 28 plots designed with RCBD. The spacing between rows was maintained at 25 cm and seed rate was 80 kg ha^{-1}. Different sources of plant nutrients including both organic and inorganic manures were applied @ 100 kg N ha^{-1} in the field. Nitrogen, phosphorus and potash was applied as recommended @ 100:60:40 kg NPK ha^{-1} through urea (46 % N), DAP (18 % N and 46 % P2O5) and MOP (60 % K2O). Half dose of Nitrogen and full dose of phosphorus and potash (50:60:40 kg NPK ha^{-1}) were applied before final land preparation as basal dose treatments. Remaining half dose of N was applied in two split doses at active tillering stage and panicle initiation. The amount of different organic composts used on the experiment is presented in table 3. Two weeding operations were performed at 25 and 45 days after seeding (DAS). No chemicals were used to control insects and disease because no significant damage was recorded to the crop. The crop from the net plot area (1 meter square) was harvested manually with the help of sickles. Harvested plants were left in-situ in the field for 3 days for sun drying. Threshing was done manually and grains were cleaned by winnowing and weighted. After threshing, the grain and straw of individual plot were separated. The moisture of the grain was taken by portable moisture meter for each individual plot. The grain yields of net plot were adjusted at 12 % moisture level and calculated with the help of following formula.

$$\text{Grain yield (kg /ha) at 12 \% moisture} = \frac{(100 - \text{MC}) \times \text{ Plot yield (kg)} \times 10{,}000\ (m^2)}{(100 - 12) \times \text{ net plot area} (m^2)}$$

Where, MC is the moisture content in percentage of the grains.

Grain yield from net plot of 1 m^2 was measured for all the treatments and plots and mean was calculated.

EFFECTS OF TREATMENTS ON THE SOIL

The soil sample was taken from each plot after crop harvest then organic matter content, total nitrogen, available phosphorus, and available potassium was analyzed.

STATISTICAL ANALYSIS

All the recorded data were subjected to analysis of variance and Duncan's Multiple Range Test (DMRT) was used for mean separations as per Gomez and Gomez (1984). MSTAT-C Microsoft computer programs were used for running statistical analysis.

RESULT AND DISCUSSION

GRAIN YIELD

Result revealed that the grain yield (Table 4) of upland rice ranged from 1.63 t ha^{-1} to 2.33 t ha^{-1} with the average of 1.89t ha^{-1}. The chemical fertilizer applied plots produced significantly ($p = 0.05$) higher grain yield (2.34t ha^{-1}) and was statistically at par with that of fresh biogas effluent (2.189 t ha^{-1}) and decomposed biogas effluent (2.050 t ha-1) applied plots. The lowest grain yield

(1.634 t ha^{-1}) was produced from ashok dry leaves compost applied plots and was statistically at par with the grain yield of rest of the nutrient sources except with chemical fertilizer and fresh biogas effluent applied plots (Table 4).

Higher grain yield of upland rice in chemical fertilizer could be because of the nutrient elements in the mineral fertilizer were in the readily available form, whereas more time could be taken in mineralization of organic manure. The grain yield of rice was higher in chemical fertilizer applied plot and that was statistically at par with fresh and decomposed biogas effluent applied plot. It was supported by Fulford (1978) and Acharya (1961). The higher yield with fresh biogas effluent was attributed to contain higher percent of mineral nitrogen (1.6 %) and was readily available than the decomposed effluent (less than 0.5 %) (Karki, 1997). Decomposed effluent had narrower C:N ratio as compared to farm yard manure, ashok dry leaves compost and rice husk so that the former gave better crop yield than the latter (Schulz, 1990).

EFFECT OF ORGANIC NUTRIENT SOURCES ON SOIL

ON SOIL ORGANIC MATTER

The highest soil organic matter content (2.716 %) was determined in fresh biogas effluent applied plots which was significantly ($p= 0.05$) higher than the rest of the treatments and was statistically at par with decomposed biogas effluent (2.630) applied plots (Table 4). The lowest organic matter content (1.694 %) was observed in chemical fertilizer applied plots followed by that of the banmara compost (1.949 %), farmyard manure (2.261 %), and rice husk compost (2.441 %). It was supported by (Wells *et al.*, 2000) that soil organic matter content decreased by chemical fertilizer and increased by the application of all types of organic manures.

NITROGEN CONTENT

The nitrogen content of the soil of upland field was initially 0.0937 %. After application of decomposed biogas effluent, fresh biogas effluent, chemical fertilizer, FYM, ashok dry leaves compost, banmara compost, and rice husk compost, the nitrogen content of the soil was 0.1353 %, 0.1313 %, 0.1225 %, 0.1217 %, 0.1128 %, 0.097 %, and 0.0842 % respectively. There was no significant ($p= 0.05$) difference on the soil nitrogen content among the treatments. The highest (0.1353 %) increment in nitrogen content was observed in fresh biogas effluent applied plots and it was statistically at par with the rest of the treatments. The lowest nitrogen content (0.08425%) was observed in rice husk compost applied plots (Table 4).

PHOSPHORUS CONTENTS

The phosphorus content of the soil of upland rice field was initially 12.061 kg ha^{-1}. The phosphorus content of the soil was 42.86 kg ha^{-1}, 37.37 kg ha^{-1}, 36.35 kg ha^{-1}, 34.12 kg ha^{-1}, 31.01 kg ha^{-1}, 29.79 kg ha^{-1}, and 24.97 kg ha^{-1} after the application of fresh biogas effluent, decomposed biogas effluent, chemical fertilizer, rice husk compost, ashok dry leaves compost, FYM, and banmara compost respectively. Significantly ($p= 0.05$) higher phosphorus content (42.86 kg ha^{-1}) of the soil was obtained from the fresh biogas effluent applied plots than others and that was statistically at par with decomposed biogas effluent (37.37 kg ha^{-1}) applied plots. The lowest phosphorus content (24.97 kg ha^{-1}) was obtained in banmara compost and was statistically at par with the farmyard manure (29.79 kg ha^{-1}) applied plots (Table 4). Chemical fertilizer, rice husk compost, and ashok dry leaves compost had similar effect on soil phosphorus content.

POTASSIUM CONTENT

The potassium content of the soil of upland rice field was initially 24.8376 kg ha^{-1}. Significantly (p= 0.05) higher (46.49 kg ha^{-1}) content of potassium was observed in fresh biogas effluent applied plots and was statistically at par with decomposed biogas effluent (44.11 kg ha^{-1}) and farmyard manure (44.11 kg ha^{-1}) applied plots. The lowest content of soil potassium (27.24 kg ha^{-1}) was obtained from chemical fertilizer applied plots followed by the banmara compost (32.06 kg ha^{-1}), and ashok dry leaves compost (39.29 kg ha^{-1}) applied plots (Table 4).

Table 4. Effect of different sources of nutrient on available nitrogen, phosphorus and potassium, field experiment at IAAS, Rampur, Chitwan, Nepal

Treatments	Grain Yield (t ha^{-1})	Organic matter(%)	Nitrogen (%)	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
Farmyard manure	1.675bc	2.261d	0.123a	29.79de	44.11ab
Decomposed biogas effluent	2.050abc	2.630ab	0.135a	37.37ab	44.11ab
Fresh biogas effluent	2.189ab	2.716a	0.131a	42.86a	46.49a
Banmara compost	1.670bc	1.949e	0.097a	24.97e	32.06d
Ashok dry leaves compost	1.634c	2.460bc	0.113a	31.07cd	39.28c
Rice husk compost	1.718bc	2.441c	0.084a	34.12bcd	41.68bc
Chemical fertilizer	2.337a	1.694f	0.123a	36.35bc	27.24e
SEM±	0.1651	0.05916	0.01581	1.854	1.213
LSD0.05	0.4905	0.1758	NS	5.507	3.604
CV%	17.44	5.08	4.45	10.97	6.18

Treatments means followed by common letter (s) within column are not significantly different among the treatments (DMRT at 5% level of significance; NS, Non significant).

The higher content of N, P and K in organic manure applied plots might be due to the improvement of other physical and chemical properties for organic manure application compared to the chemical fertilizer application. Ullah *et al*. (2008) observed the lowest value of K from chemical fertilizer application. Yu *et al*. (2009) found that application of biogas effluent increased the organic matter content, available N, P, and K; and total N and P. Karki (2001) observed increased total organic matter, phosphorus, potassium and nitrogen content through application of biogas effluent either fresh or decomposed in the soil than chemical fertilizer.

CONCLUSION

Organic manures are the core of organic farming which supply most of the nutrients and improve the overall properties of the soil. In this study, the significantly (p= 0.05) higher grain yield (2.337 t ha^{-1} grain) in chemical fertilizer applied plots were statistically at par with fresh biogas effluent (2.189 t ha^{-1}) and decomposed biogas effluent (2.050 t ha^{-1}). The highest soil organic matter content (2.716 %) was determined in fresh biogas effluent applied plots which was significantly (p= 0.05) higher than the rest of the treatments and was statistically at par with decomposed biogas effluent (2.630) applied plots. The lowest organic matter content (1.694 %) was observed in chemical fertilizer applied plots followed by that of the banmara compost (1.949 %), farmyard manure (2.261 %), and rice husk compost (2.441 %).With respect to the soil, it was obtained that there was more increment of organic matter, N, P, and K with the use of biogas effluent either fresh or decomposed than chemical fertilizer. Thus, it was concluded that biogas effluent is the best source of nutrient among the organic manures and sound alternative to inorganic fertilizer. Further experimentation on the issue for further verification of the information obtained so far is suggested.

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ANALYSIS OF VEGETABLE VALUE CHAIN IN RASUWA DISTRICT OF NEPAL

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ABSTRACT

The study focuses on conducting scenario analysis of various stakeholders engaged in promoting vegetable in Parvatikunda Rural Municipality of Rasuwa district. 50 respondents and 20 stakeholders were interviewed via random sampling method. The survey was conducted in june 2017.The actor analysis matrix showed that Parvatikunda rural municipality office of Rasuwa district had the most influence in decision making followed by I/NGOs and hotels and restaurants. Farmers who were directly involved in production of vegetables had lower influence in decision making. However, role of district agriculture development office was identified as the most important for successful and profitable vegetable farming in Parvatikunda Rural Municipality. Farmers, though did not have more influence in decision making, were identified as important stakeholders to contribute for profitable vegetable farming in Parvatikunda Rural Municipality. This indicated that the strategy for strengthening vegetable value chain in Parvatikunda Rural Municipality should be modified based on importance and contribution of each stakeholders in vegetable value chain in Parvatikunda Rural Municipality of Rasuwa district. The importance-influence matrix showed that role of Parvatikunda Rural Municipality and DADO should be considered the most. They are highly important and influential in making decision and contributing in vegetable value chain in Parvatikunda Rural Municipality. Similarly, farmers groups should be targeted with due importance in vegetable value with some sorts of influential role. As major proportion of vegetables produced in Parvatikunda Rural Municipality are consumed locally, the trekkers can be considered less important with low influential ability in decision making and contributing to strengthen vegetable value chain in Parvatikunda Rural Municipality. Role of I/NGOs and Agro-vet was also considered very important for production and supplying inputs respectively.

Key words: Vegetable, margin, market, stakeholder analysis, value chain

INTRODUCTION

Agriculture in Nepal has long been based on subsistence farming, particularly in the hilly regions where locals derive their living from fragmented plots of land cultivated in difficult conditions. The economic well-being of Nepal is very closely bound to its natural resources – arable land, water, and forest areas. Horticulture contributes about 14 percent to the total agricultural gross domestic products (AGDP) (Thapa, 1998). The share of horticulture to the AGDP has increased in recent years. The vegetable intake by Nepali people is very low compared to this standard, with a deficiency of 60 percent in relation to vegetable production (Gautam and Bhattarai, 2006). Growing demand of vegetables is increasing day by day due to a major shift by people living in the country to healthy

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food. Vegetables have become an integral part of a balanced diet, and play a vital role in providing nutritional security. A result has been an improvement in the financial situation among a majority of small-scale farmers.

Rasuwa is also one of the 14 most effected districts by the devastating earthquake of April, 2015. The earthquake resulted huge loss in livestock and agriculture Impact on agriculture based livelihood was found to be devastating; farmers lost their crops, seed stocks, livestock and even agriculture lands in many places were avalanched (NPC, 2015 PDNA). In turn, earthquake trapped down the sluggish but trying to take off agribusiness sector in the district. However, coordinated efforts from the government, development partners, civil societies and private partners has started rejuvenating the agriculture sector but still needs continuous and focused initiatives to foster the sector. Rasuwa district bears the tremendous potentialities for agricultural development through vegetable farming and livestock rising. Vegetables are generally grown without using chemicals and thus have got competitive advantage over vegetables grown using chemical fertilizers and pesticides. Organically grown vegetables fetch relatively higher price in comparison to nonorganic vegetables. Organic vegetables of Rasuwa district are always under preference of tourist, restaurants and hotels. However, farmers are not satisfied with the price they have received by selling vegetables. Farmers do not have access to price fixation and significant percent of producers' share goes to middle men. Farmers, important actors in vegetable value chain, generally lack access to decision making in terms of market and price. There are several institutions involved in putting steps for commercialization of vegetables in Rasuwa district. However, their importance and influence in decision making in every value chain functions have not been analyzed properly. This has ultimately affected in making vegetables promotion strategy in Rasuwa districts. Thus, this study aims in conducting scenario analysis along the vegetable value chain in Rasuwa district of Nepal.

OBJECTIVES

General objective of this research was the value chain analysis of vegetable in Rasuwa district. The specific objectives were to:

- To perform the actor analysis in vegetable value chain
- To study the importance-influence relationships of stakeholders in vegetable value chain
- To recommend the market based solution to the vegetable growers

METHODOLOGY

Parvatikunda rural municipality was purposively selected to assess the situation of vegetable value chain in high mountain districts of Nepal in June, 2017. Similarly, 50 farmer respondents and 20 stakeholders were randomly selected for survey. Semi structured questionnaires were prepared and enumerators oriented in the study site. Secondary information collected from district agriculture office, Parvatikunda rural municipality, local NGOs, district chambers of commerce and other value chain actors. Information resourced through observation, focus group discussion, and key informant survey.

1. STUDY SITE

Rasuwa is one of the 16 Himalayan districts of Nepal. It bears the unique characteristics of having tropical to temperate climatic environment that ranges from 675 to 7234 masl. It is the smallest among all 16 Himalayan districts having area of 151200 hectares of land, of which 12458 ha of land is cultivable. The total number of households in the district is 9,778, (CBS, 2011). Majority of population rely on agriculture for their livelihood. Crops and livestock are the major parts of agricultural system in Rasuwa districts. Parvatikunda rural municipality is local government unit of Rasuwa district of Nepal. The rural municipality comprises well known trekking trail. It is sparsely populated local unit inside the district due to its remoteness and abundance of single traditional community. The major sources of livelihood in the area are agriculture (vegetable production and yak farming) and tourism. Nevertheless, the sector lacks sufficient efforts for commercialization.

2. METHODS AND TECHNIQUES OF DATA ANALYSIS

2.1 MARKETING MARGIN AND GROSS MARGIN ANALYSIS

Marketing margin is the outcome that we get subtracting farm gate price from price paid by the consumer or retailer's price.

Marketing margin= Retailer price (P_r) – *Farm-gate price* (P_f)

Similarly, Gross margin analysis is the difference between total value of product and variable cost associated to particular enterprise. Only variable costs were included for this analysis.
The gross margin was calculated as:

Gross margin = Gross return – Total variable cost

2.2 BENEFIT COST ANALYSIS (BCA)

Benefit cost ratio is the ratio of gross return and total cost of production under study. Gross return was calculated as the revenue from the product sales while the total cost was obtained by summing the variable costs and fixed costs incurred in the production process. So, the B/C ratio was obtained from the formula as under;

B/C ratio = Gross return / total cost

2.3 STAKEHOLDER'S ANALYSIS

Stakeholders analysis generally consists of two components i.e. actor analysis matrix and importance-influence matrix. It was conducted through discussion with farmers, key informants, elected local representatives and agricultural experts. It was mainly based on role of stakeholders in decision making and their importance in value chain. The responses on decision making role and impact (contribution for success and failure of program) was quantitatively defined by number starting from one to number of stakeholders involved, where one represented the least importance and least impact.

2.4 IMPORTANCE-INFLUENCE MATRIX

In order to strengthen vegetable value chain to ensure benefits to all actors along the chain, importance and influence of each stakeholder should be identified. Importance-Influence Matrix was prepared by consulting subject matter specialist from DADO, Rasuwa, Parvatikunda Rural Municipality, Local NGOs and other related stakeholders. The result of importance-influence matrix to make all actors in vegetable value chain benefited is presented in table below:

2.5 VALUE CHAIN MAPPING

Value chain analysis comprises the assessment of marketing system, marketing channels, marketing margin, producer's shares and marketing efficiency (Kaplinsky and Morris, 2000). Value chain analysis approach was used here to study the production system, marketing system, marketing channels, marketing margin, producer's shares and marketing efficiency of agricultural commodities under study in Parvatikunda Rural Municipality Rasuwa district. Each and every step involved in transforming a commodity from producer to consumer was closely examined. Value of commodities under study in each form while passing through different market players were analyzed economically.

RESULTS AND DISCUSSION

1. STAKEHOLDERS ANALYSIS

In the current study stakeholders analysis was conducted to identify the different stakeholders in vegetable value chain in Parvatikunda rural municipality with their importance and impact on decision making. The primary objectives of conducting stakeholders analysis was to identify all those (people, groups or institutions) who might be affected by an intervention or can affect its outcome; mobilize key stakeholders for strengthening vegetable value chain; identify local institutions and processes upon which to build and to provide a foundation and strategy for involvement in vegetable sector in Parvatikunda rural municipality. The stakeholder's analysis generally consists of two sub headings: Actor analysis matrix and Importance-Influence Matrix as shown in the table below:

2. ACTOR ANALYSIS MATRIX

ANM consists of two elements i.e. position on decision making and impact on the project outcome. Position of each stakeholder in vegetable value chain is its status in the decision-making system. It deals with what extent do the different stakeholders have a mandate, policies, knowledge, network or other 'power' in relation to other actors in the programme. Similarly, impact indicates to what extent the stakeholders contribute towards the successful (or failing) outcome of the project. In order to assess the position and impact each stakeholders in value chain of vegetables in Parvatikunda RM were ranked from 1 (low position/importance) to highest score (total number of actors). The total number of actors were identified after completing of key informant survey and focus group discussion. The results of actor analysis is presented in the table below:

Table 1. Actor analysis matrix

Stakeholders	Primary activities	Position (influence in decision making)	Impact (contribution to successful (or failing) outcomes of vegetable development program)
ASC/District Agriculture Development Office	Technology dissemination	6	9
Rural Municipality Office	Resource allocation	9	7
Farmers/FGs/Coops	Production	5	6
Local Traders	Marketing	3	3
I/NGOs	Advocacy, training	8	8
Agrovets	Input supply	2	2
Transporters	Transporting and trading	4	1
Hotels and restaurants	Keeping vegetables for serving meal or dinner to tourists and others	7	5
Trekkers	Taking vegetables to home after trek	1	4

The actor analysis matrix showed that Parvatikunda rural municipality office of Rasuwa district had the most influence in decision making followed by I/NGOs and hotels and restaurants. This indicates that most of decision in vegetable value chain in Parvatikunda RM was influenced by these stakeholders. Farmers who were directly involved in production of vegetables has lower influence in decision making. However, role of district agriculture development office was identified as the most important for successful and profitable vegetable farming in Parvatikunda Rural Municipality. The contribution of I/NGOs was also identified as important. Farmers, though did not have more influence in decision making, were identified as important stakeholders to contribute for profitable vegetable farming in Parvatikunda Rural Municipality. This indicated that the strategy for strengthening vegetable value chain in Parvatikunda Rural Municipality should be modified based on importance and contribution of each stakeholders in vegetable value chain in Parvatikunda Rural Municipality of Rasuwa district.

3. IMPORTANCE-INFLUENCE MATRIX

In order to strengthen vegetable value chain to ensure benefits to all actors along the chain, importance and influence of each stakeholder should be identified. Importance-Influence Matrix was prepared by consulting subject matter specialist from DADO, Rasuwa, Parvatikunda Rural Municipality, Local NGOs and other related stakeholders. The result of importance-influence matrix to make all actors in vegetable value chain benefited is presented in table below:

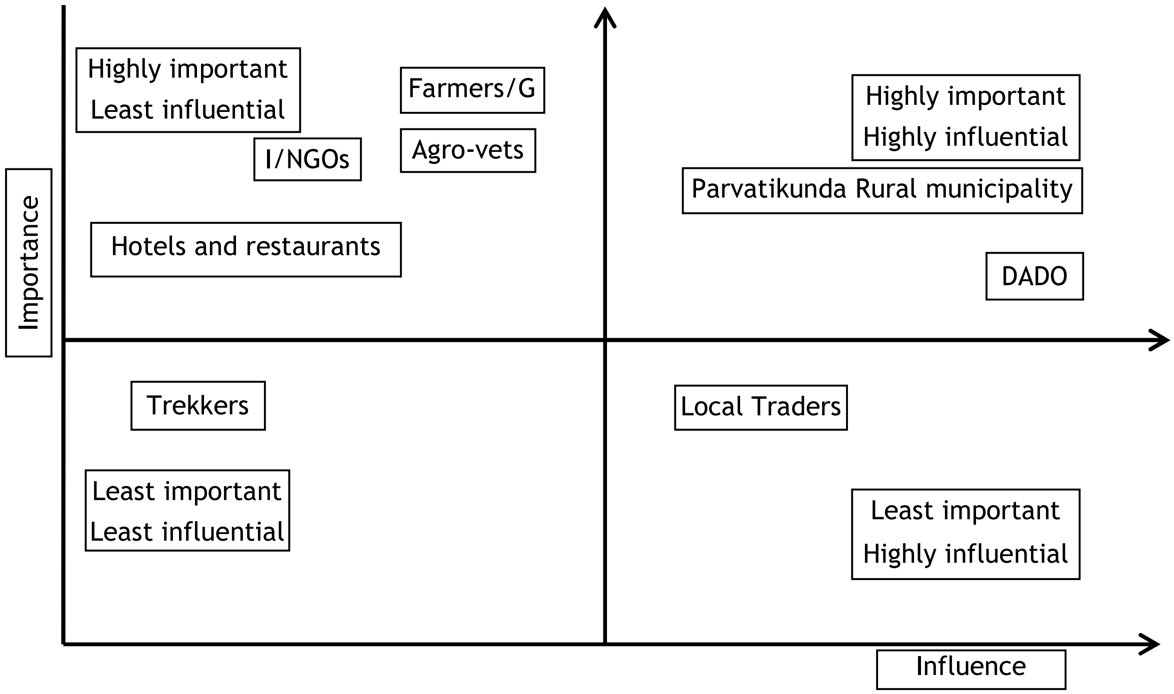

Figure 1. Importance-Influence Matrix

The importance-influence matrix of various stakeholders in vegetable value chain in Parvatikunda Rural Municipality showed that role of Parvatikunda Rural Municipality and DADO should be considered the most. They are highly important and influential in making decision and contributing in vegetable value chain in Parvatikunda Rural Municipality. Similarly, farmers groups should be targeted with due importance in vegetable value with some sorts of influential role. As major proportion of vegetables produced in Parvatikunda Rural Municipality are consumed locally, the trekkers can be considered less important with low influential ability in decision making and contributing to strengthen vegetable value chain in Parvatikunda Rural Municipality. Role of I/NGOs and Agro-vet was also considered very important for production and supplying inputs respectively.

4. VALUE CHAIN MAPPING OF VEGETABLES IN PARVATIKUNDA RURAL MUNICIPALITY

Value chain analysis is a tool that used to define development opportunity, looking at each discrete step in the life of a product, the players at each step, how value is added, and how much they earn for that value created (Piper, 2007, cited in Bastola, 2007)). It provides a convenient framework to study the impacts of economic, technological and institutional changes through global marketing chains and the distribution of the incidence of those impacts and any gains arising from them between participants at different production and marketing stages. It seeks to address the major constraints at each level of the supply chain, rather than concentrating on just one group or on one geographical location (Dempsey and Campbell, 2007). The heart of the value chain analysis is the mapping of sectors and key linkages. The value-added of the value-chain approach, however, comes from assessing these intra- and inter-actor linkages through the lens of issues of governance, upgrading, and distributional considerations. Understanding these linkages within a network, one can better prescribe policy recommendations and, moreover, further understand their reverberations throughout the chain.

A value chain consists of all stages of a technical production process as well as of the interaction between these stages. The production process starts at the stage of input supply, than covers production, processing and marketing and ends with the consumption of a certain product. It can be seen as the hard skill of a value chain (Schipmann, 2006). Besides the technical structure, also the actors of a value chain as well as the input-output, and the territorial structure define a value chain (Gereffi, 1994)

Value chain map simply represents how the product passes from different value chain functions. Value chain map of vegetable in Parvartikunda Rural Municipality showed the different functions, major actors performing the functions and supporting agencies for strengthening vegetable value chain in the rural municipality. Input supply, production, retailing and consumption were three value chain functions identified during survey of this study. Agrovets, Farmers/G/Coops, local traders, local consumers, trekkers were identified as major actors performing various value chain functions. The schematic vegetable value chain map in Parvatikunda Rural Municipality is presented in diagram below:

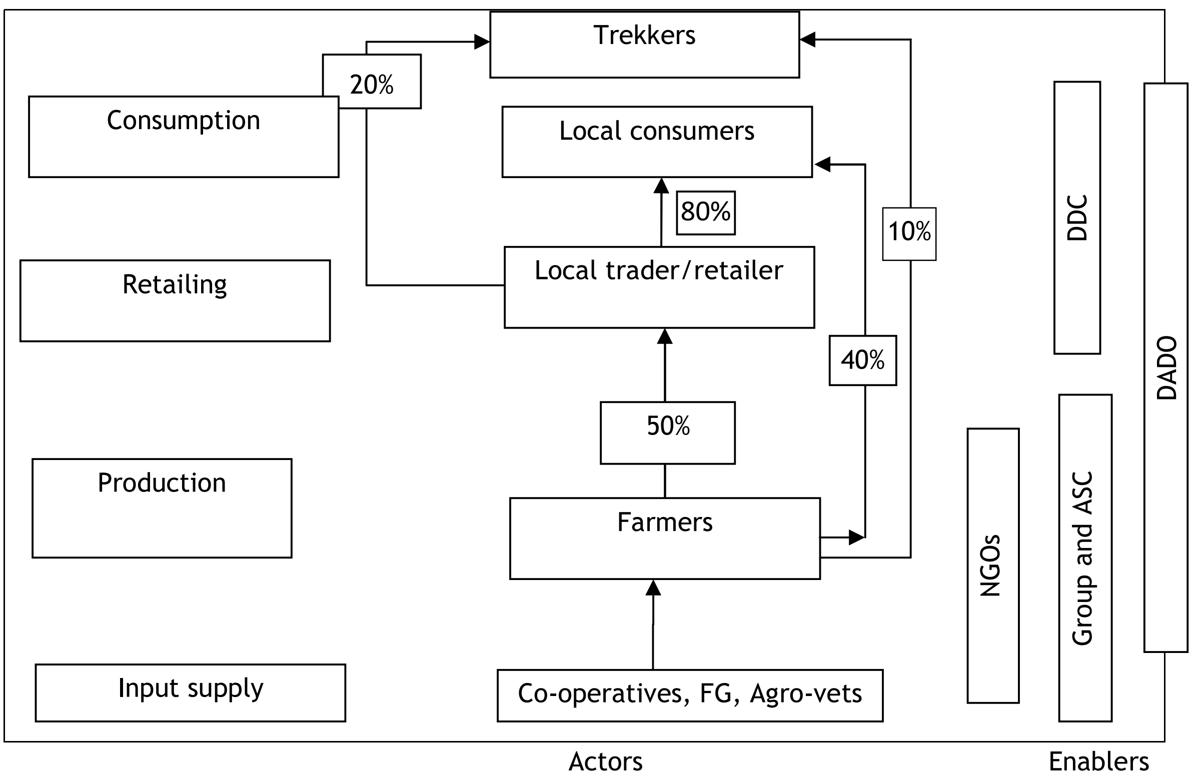

Figure 2. Value chain map of Vegetable in Parvatikunda Rural Municipality

5. FUNCTIONS AND ACTORS

a. **Input Suppliers:** Local agro-vets were the major actor performing the function of input supply. Inputs are the basic needs for vegetable production. Seeds, fertilizers, bio pesticides and organic fertilizers were mainly supplied by input supply in vegetable value chain of Parvatikunda Rural Municipality.

b. **Producers:** Farmers/FGs/Coops were the major producer of vegetables. They used to sell their produce mainly to local traders. About 40 percent of vegetables were directly supplied to consumers at Rasuwa district and 10% vegetables were taken away to Kathmandu or other places by tourists coming for trekking in Rasuwa district.

c. **Retailers:** Local traders were found to perform the retailing function in vegetable value chain. Buying and supplying vegetables to retail shop/consumers was the major function of retailer in vegetable value chain in Parvatikunda Rural Municipality. The study found that 80 percent of produces that retailers have was supplied directly to consumers at Rasuwa district,. 20 percent of produces was channelized to trekkers who come to Rasuwa district for trekking.

d. **Consumers:** Local people, some of the tourists coming to Rasuwa were the major consumer of vegetables produced in Parvatikunda Rural municipality of Rasuwa district. Some trekkers used to carry fresh vegetables during their return to home after trekking.

6. ENABLERS AND FACILITATORS

District Agriculture Development Office, Parvatikunda Rural Municipality, Small and cottage Industry Development Office were the supporting agencies for strengthening vegetable value chain in study area. Proving technical supports, disbursing loan to farmers, agreements on professional standards were some of the function of supporting agencies in vegetable value chain in Parvatikunda Rural Municipality.

7. COSTS AND GROSS MARGIN

All costs of the product incurred before it reaches the terminal market (consumer) are generally included in the cost stream of economic analysis. This includes cost of harvesting and packaging (material and labor costs), handling (sorting, cleaning, grading, loading and unloading), transportation, processing etc. Generally, these components constitute a large share in the total margin between the final retailer price and the cost of production (or farm-gate price). The margin is calculated to show the distribution of profits throughout the various actors as the vegetables move from production to the consumers. The summary of gross margin is presented in the table below.

Table 2. Gross margin at different levels

Crop	Farm gate		Collector/Local trader		Wholesaler		Retailer	
	Price	Margin	Price	Margin Received	Price	Margin Received	Price	Margin Received
Vegetable (Leafy vegetables and Cole crops)	45	00	50	5	60	10	75	15

8. OPPORTUNITIES AND CONSTRAINTS IN VEGETABLE VALUE CHAIN

Increase in general awareness of the nutritional values of vegetables among the people has increased tremendous scope of promoting the production and marketing of fresh vegetable. Looking at the trend, the total demand for vegetable is projected to expand considerably in the near future. It has been widely realized by several researchers that Rasuwa has comparative advantage in some of the fresh vegetables.

9. OPPORTUNITIES AND CONSTRAINTS

Type	Strength	Opportunities	Constraints	Threats
Market access	• High quality of produce	• Increased market access	• Inadequate market information and pricing mechanism • Lack of organized market	• Transportation blockades, climate etc
Input supply	• Availability of local input material. • 12 agro-vets at district headquarters	• Organic production	• Lack of bio fertilizers and pesticides, inadequate knowledge on organic farming	• Lack of dependable means of transportation
Technology and product development	• Availability of service providers • Agriculture section at rural municipality • NGO/INGOs working for technology dissemination	• Increased productivity • Increased farmers' income • Commercialization	• Inadequacy of seed and other inputs at production pockets • Poor access to production and postharvest handling technology at farmers and trader leve	• Chances of being agriculture sector as non-prioritized sector during restructuring of government institution, • Farmers could be reluctant to adopt new technology
Access to finance	• Bank and finance	• Agribusiness development	• People show poor performance due to lack of knowledge	• Chances of being least prioritized sector for loan flow
Infrastructure	• Extension of roads going on and irrigation expanding • Availability of land for cold storage and market structure	• Commercialization	• Basic infrastructures (road, irrigation) poorly available; Still lack of year round functioning roads and irrigation • Lack of cold storage	• Chances of not having adequate resources from government

10. IDENTIFICATION OF MARKET-BASED SOLUTIONS

It is crucial to assess the market-based solutions to study their feasibility and sustainability and to clarify the offer of and the demand for the solution.

11. MARKET BASED SOLUTIONS ADDRESSING VALUE CHAIN CONSTRAINTS

Value chain Constraints	Market Based Solutions
Low volume of production not meeting the requirements of buyers	• Vegetable production zoning • Timely availability of quality inputs (seeds, fertilizer) • Training on production and postharvest handling of vegetables
Poor market information and pricing mechanism	• Easier access to reliable market information though collaboration between traders, and media agencies
Lack of knowledge on post-harvest handling	• Training on grading, packaging, processing and quality standards to lead farmers, local traders, wholesaler and retailer
Poor knowledge on entrepreneurship development	• Provision of business planning and enterprise development training to farmers and local traders
Poor access to Banks and microfinance institutions to farmers and traders	• Access to microfinance to farmers and local traders
Poor infrastructure	• Establishment of collection centers in pockets • Provision of a well-equipped wholesale market in district headquarter
Poor technological knowledge with agro-vet owners and lack of agro vet	• Technological training to agro-vet owners.

12. MARKET BASED SOLUTIONS

Market Based solution for sector	Service provider and users	Constraints	Possible areas of project intervention/facilitation
vegetable	• DADOs/ASC • Technicians • NGOs	• Inadequacy of quality seed and other inputs at production pockets at appropriate time • Lack of Appropriate Technology • Low volume of production not meeting the requirements of buyers	• Development of offseason vegetable zone • Introduction of permanent poly house technology can serve as an appropriate technology to produce vegetables in large volume and in off season also • Training on production, grading and quality standards as well as post-harvest handling to farmers • Using of closed tunnel to grow vegetable can protect them from damages due to hen and also harsh climatic conditions • Opportunity for organic production in the area
Production and marketing	• NGOs • Cooperatives • Farmers	• Farmers and trader level	• Develop linkage of input providers with farmers

Training on entrepreneurship development	• BDS providers (Private, National NGO, INGO)	• Lack of information among farmers, collection centers, processors and other local enterprises on BDS providers and their services to farmers	• Provide business planning and enterprise development training to collection centers, and traders through BDS providers (private, NGO, LNGO) • Provide training on woolen products and handicraft preparation
Easy access to microfinance to farmers	• Microfinance Institutions • Commercial banks	• Lack of linkage to MFIs by cooperatives and groups • Low knowledge of traders and commercial farmers on development of proper financial plans	• Assess the demand for finance from farmers and facilitate to establish linkage between their groups/cooperatives with MFIs
Establishment/ up gradation of collection centers, storage house and cold storage	• DADOs • Donors • I/NGOs	• Lack of assessment (including impact and number of beneficiaries) of potential sites for infrastructure development	• Identification and assessment of potential sites for development of infrastructure which can provide greater impact and wide base of beneficiaries • Provide financial assistance for establishment of infrastructure

CONCLUSION AND RECOMMENDATIONS

There is huge potentiality of agriculture and livestock in Parvatikunda rural municipality of Rasuwa district, many institutions have been working for increasing income of farmers through promotion of vegetables in Parvatikunda rural municipality. The study showed that rural municipality, District Agriculture Development offices and farmers are the most important stakeholder to contribute for promoting vegetables sector in Parvatikunda Rural Municipality. Farmers must be trained well regarding improved vegetable farming. Study showed that the role of stakeholders should be modified based on their importance and influence in value chain map of vegetables in Parvatikunda Rural Municipality. The study concluded the introduction of permanent poly house technology, training on production/business planning and enterprise development, subsidy on seed/organic manure and construction of collection center for efficient marketing of products were found area of intervention in study site.

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IN VITRO EFFICACY OF DIFFERENT BOTANICALS FOR THE CONTROL OF ALTERNARIA ALTERNATA AND RHIZOCTONIA SOLANI

Shrinkhala Manandhar[1], Ajaya Karkee[2], Chetana Manandhar[1], Bimala Pant[1] and Suraj Baidya[3]

ABSTRACT

An in vitro experiment was carried out for testing the efficacy of various phytoextracts by adopting poisoned bait method against Alternaria alternata (isolated from Aloe vera) and Rhizoctonia solani (isolated from tomato) in Plant Pathology Division, Nepal Agricultural Research Council during 2016. Eucalyptus globolus leaf extract was found superior for inhibition of both mycelial growth and sporulation of A. alternata followed by Asparagus racemosus root extract. However, for the control of R. solani, asparagus was found to be the best followed by eucalyptus. Some plant extracts (Lantana camara, Clove) were found to accelerate the growth and sporulation of A. alternata whereas all of the tested plant extracts for R. solani were found to inhibit its growth with varying degrees of antagonism. Banning of chemical pesticides due to their harmful effects on health and environment has led to seeking of eco-friendly substances and hence in vitro assays in preliminary phase are important for screening of the effective botanicals. The botanicals found with antagonistic properties in this study should be further tested in field conditions to verify their efficacy as well as for any phytotoxic effects and to determine their optimum doses of application.

Keywords: *Alternaria alternata*, phyto-extracts, mycelial growth, *Rhizoctonia solani*, sporulation

INTRODUCTION

Alternaria alternata is an ascomycete fungus which produces asexual spores. It causes leaf spot disease in *A. vera* which can have significant losses in yield of the plant (Anamika and Simon 2011). The disease is identified by dark brown necrotic circular to oval sunken lesions with concentric ring (Regmi et al 2014). Infection by the pathogen destructs the host's mesophyll tissue and decreases its antimicrobial properties (Ghosh et al 2016). Consequently, the medicinal and cosmetic value of the plant is adversely affected (Chavan and Korekar 2011). *Rhizoctonia solani* is a soil borne pathogen having a wide host range including vegetables, cereals, legumes and ornamentals (Garcia et al 2006). It is a Basidiomycete fungus which does not produce asexual spores. The pathogen produces dark brown sclerotia which are the survival structures of the pathogen and can persist in soils for long periods of time (Agrios 2005). Depending on the affected host, it causes symptoms like root rot, collar rot, damping off, wire stem, web blight and sheath blight (Garcia et al 2006). In tomato, *R. solani* causes root rot which is mostly at seedling stage as the pathogen thrives in soil. Chemical pesticides exhibit fast action over pathogens but they also have residual effect on commodities (Regmi et al 2014). Hence chemical pesticides may not be desirable for the management of disease for medicinal plants or for any edible commodities. Besides, development of virulent pathotypes/races by the use of chemical pesticides cannot be overseen (Yoon et al 2013). Eco friendly substances are being opted for the management of plant diseases because of no negative impacts on environment and human health and no residual threats (Zaker 2016). Hence in

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searching of eco-friendly treatments for the control of *A. Alternata* and *R. solani, an in vitro assay of* several plant extracts and two chemicals (for comparison) was carried out at Plant Pathology Division, Khumaltar.

MATERIALS AND METHODS

ISOLATION AND CULTURE OF *A. alternata* from *A. vera*

For obtaining pure culture of the pathogen, diseased parts were cut into one cm sections which were surface sterilized using 1% sodium hypochlorite for one minute and rinsed with sterile water. After drying the tissues inside laminar flow, they were placed on water agar and incubated at 25°C for two days. For *A. alternata*, single spore culture of the pathogen was performed while for *R. solani*, hyphal tip culture was done on PDA plates under aseptic conditions. The plates were incubated at 25°C for one week until full growth of the pathogen.

AMENDMENT OF PLANT EXTRACTS AND CHEMICALS IN MEDIA

Twelve different treatments were chosen for the study which included nine natural plant extracts (Castor, Datura, Tea, Clove, Cinnamom, Eucalyptus, *Lantana camara*, Asparagus, Black pepper), two chemicals (Sectin and Copper oxychloride), and one control. Plant extracts were prepared from leaves, bark, roots and dried fruits of various plant species. Fresh leaves were grinded in mixer grinder with equal amount of sterilized water (1:1 wt/vol). The extract was filtered through muslin cloth to get stock solution considered as 100% concentration and sterilized at 121°C for 15 minutes. For dry samples (root, bark, dried fruits), they were boiled @ 1:10 wt/vol water for half an hour and filtered through cheese cloth to get standard solution of 100%. The extract was then sterilized at 121°C for 15 minutes. Poisoned food technique (Schimitz 1930) was performed for the assay in which PDA media in lukewarm state was amended with 10% given test plant extracts. For chemical pesticides, chemicals with 100 ppm a.i were amended in media before pouring into 9 cm petri dishes. PDA without plant extract or chemical served as control.

INOCULATION OF PATHOGEN

Five mm circular discs of pathogens (*A. alternata*/ *R. solani*) were excised with sterile cork borer from one week old culture and placed at the centre of PDA plates under aseptic conditions. Three petri dishes were chosen as three replications for each treatment and the experiment was arranged in complete randomized design (CRD). The plates were incubated at 25°C. Measurement of the colony diameter of pathogens was taken every day for one week. Percent growth inhibition of the pathogen was calculated by using the following formula of Vincent (1947)

$$I\ (\%) = \frac{C-T}{C} X100$$

Where, I=inhibition

C =Colony diameter in control

T= Colony diameter in treatment

Spore count for *A. alternate* in different treatments was performed after one week by harvesting spores from the plates using glass slides. Dilution of the final suspension of each treatment was performed for ease in counting. The spores were counted using haemocytometer under compound microscope and total spores in each plate were calculated. As mentioned earlier, *R. solani* does not produce asexual spores and hence radial growth and its inhibition was the only parameter taken in the study.

STATISTICAL ANALYSIS

MSTATC was used for the analysis of variance (ANOVA) to test the significance of treatment effect on mycelial growth and sporulation of *A. alternata* and *R. solani*. Duncan's multiple range test (DMRT) was used to compare the values of significant treatment means at 1% level of significance.

RESULTS AND DISCUSSION

For the control of *A. alternata*, Eucalyptus showed greatest inhibition percent (30.74%) and lowest sporulation of the pathogen (9.66 X 10^6)as compared to other plant extracts. The results are presented in table 1. *Eucalyptus* was able to perform even better for decreasing sporulation than the chemical Sectin. The inhibitory effect of Eucalyptus on *A. alternate* of *A. vera* has also been previously reported in an *in vitro* assay (Jha et al 2014). Likewise, Eucalyptus has been found to be effective for *A. alternata* in various other host crops (Cabral et al 2016, Zaker and Mosallanejad 2010). Eucalyptus, in a field experiment decreased *Alternaria* leaf spot disease caused by *A. brassicae* and resulted in increase of yield of mustard seeds (Patni et al 2005). This explains the scope of the plant extract to be applied in crops for *Alternaria* control without any phytotoxic effects. Among other plant extracts, Asparagus roots showed growth inhibition of only 9.8% however spores count was significantly less (54.66 X 10^6) than control (181.33 X 10^6). In a study for the management of *A. solani* in potato, Asparagus roots were found to be effective against the pathogen (Singh et al 2015).

Lower mycelial growth inhibition was observed in treatments of Dhatura (2.9%) and Piper (6.9%). Interestingly, five of the tested plant extracts showed increased mycelial growth than control. Although, increased mycelial growth was observed in Castor, Tea and Cinnamom, these treatments showed significantly lower spore count than control. Reduction of spore formation is important in *A. alternata* because the pathogen reproduces asexually via conidia and efficiently may be spread by air. Hence lower spore count in treatments indicates that the pathogen multiplication had lowered which eventually decreases the inoculum level over time (Agrios 2005). In our study, *Lantana camara* and Clove enhanced sporulation of the pathogen which was at par with control. Similar result of growth acceleration of *A. alternata* by onion extract in sunflower was mentioned by Srinivas et al (1997). This might have resulted because the botanicals served as nutrients/stimulant for the pathogen. This necessitates for the *in vitro* assays before trying out various treatments in fields as some of these could be multiplying the inoculums present in fields. *In vivo* effect of phytoextracts against *A. alternata* in *A. vera* are lacking. Nonetheless, there are several reports of various botanicals which are proved to be effective for the management of *A. alternata* in other host crops (Srinivas et al 1997, Kumar et al 2011, Ramjegathesh et al 2011).

For the control of *R. solani*, however, all of the tested phytoextracts exhibited control over the pathogen in varying degrees and they were significantly different from control. Asparagus root extract was found to the most effective showing 45.66% of inhibition followed by Eucalyptus (28.31%) and Clove (27.39%). One important observation made was the reduced number of sclerotia in Asparagus treated plates compared to other treatments (data not shown). This could be the significant factor for management of *R. solani* as sclerotia are the survival structures of the pathogen which can persist in soils for many years. Clove and Lantana, which accelerated the growth and spore count of *A. alternata* inhibited *R. solani* growth by 27.39% and 16.43% respectively. Aye and Matsumoto (2011) reported 100% inhibition of *R. solani* using ethanol extract of Clove and ethanol extract of *Eucalyptus* resulted in 35.7% inhibition while water extract of the same botanicals exhibited less control over the pathogen growth. Sonakar et al (2014) reported Datura to be the least effective among the botanicals tested against *R. solani* in vitro. In our study, Datura gave satisfactory control of the pathogen while Cinnamom and Tea were seen as least effective to control *R. solani*. Except for *Eucalyptus*, all other plant extracts served to control *R. solani* more than *A. alternata*. This explains that a botanical which is ineffective for one pathogen can be effective against another.

Table 1. In vitro effect of phytoextracts and chemicals on *A. alternata* and *R. solani*

Treatment	*Alternaria alternata*			*Rhizoctonia solani*	
	Mean Colony diameter (cm)	Growth Inhibition (%)	Total Spore count (Per Plate)	Mean Colony diameter (cm)	Growth inhibition (%)
Sectin (Mancozeb 50%+Fenamidone 10%)	2.60h	61.38	$13.5X10^6$ (7.11)f	1.60h	78.08
Blitox 50 (Copper oxychloride 50%)	3.87g	42.55	$5.33\ X10^6$ (6.69)g	4.43f	39.26
Ricinus communis (Castor) leaves	8.27a	-22.78	$153X10^6$(8.18)ab	6.20bc	15.06
Datura stramonium (Dhatura) leaves	6.53de	2.95	$62.66\ X10^6$ (7.79)de	5.50de	24.65
Camellia sinensis (Tea) cured leaves	8.17a	-21.31	$119X10^6$(8.07)bc	6.30b	13.69
Syzygium aromaticum (Clove) dried flower buds	7.50abc	-11.38	$206.66\ X10^6$ (8.31)a	5.30e	27.39
Cinnamom umverum (Cinnamom) bark	7.17bcd	-6.96	$97.33\ X10^6$ (7.97)cd	6.40b	12.32
Eucalyptus globolus (Eucalyptus) leaves	4.67f	30.74	$9.66X10^6$(6.9)f	5.23e	28.31
Lantana camara leaves	7.03bcd	-4.46	$188\ X10^6$ (8.27)a	6.10bc	16.43
Asparagus racemosus dried roots	6.07e	9.87	$54.66\ X10^6$ (7.72)e	3.96g	45.66
Piper nigrum (Black pepper) dried fruits	7.57ab	6.96	$172\ X10^6$ (7.91)cde	5.83cd	20.09
Control	6.70cde	0.0	$181.33X10^6$(8.25)ab	7.30a	0.00
LSD	0.02		0.19	0.44	
P value	<0.001		<0.001	<0.001	
CV	3.22		1.48	4.95	

Means followed by the same letter in a column are not significantly different (DMRT, P< 0.001). Values in parentheses for spore count are log transformed values

CONCLUSION

The present study found Eucalyptus leaf extract to be satisfactory for mycelial growth inhibition and superior in terms of reducing sporulation of *A. alternata*. Similarly, for the control of *R. solani*, Asparagus root extract was found to be effective. These findings need further verification by application of the treatment in infected host plants to see for any phytotoxic effect and to find out the degree of control over the pathogen in viv*o* conditions.

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PRODUCTION AND PRODUCTIVITY ASSESMENT OF HYBRID RICE THROUGH DIFFERENT NUTRIENT MANAGEMENT PRACTICES IN KAVREPALANCHOWK DISTRICT

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ABSTRACT

Nepal Government recommended the blanket fertilizer application methods for rice which causes either over, under or improper balance of nutrients for crop. An experiment was conducted at Kavrepalanchok during 2016 to study the effect of various nutrient management practices in production and productivity of rice. Altogether six treatments comprising various nutrient management practices viz. Jholmal, Nutrient Expert Model (NE), use of Leaf Color Chart (LCC), Government Recommended Fertilizer Dose (RDF), Farm Yard Manure (FYM), Farmers' Field Practice (FFP), were laid out in RCBD in four farmers' fields as replications. During the study, Plant height was significantly different in all the treatments. Significantly longer panicle (28.16 cm), higher number of grains/panicle (273.80) and test weight (17.50 gm) were observed in NE which resulted in significantly higher yield (5.84 ton/ha) with higher harvest index. Thus, higher grain yield can be achieved by transplanting rice crop early and managing nutrients using NE Model.

Key Words: Farm yard manure, jholmal, leaf color chart, nutrient expert, yield

INTRODUCTION

Agriculture contributes nearly 32.72 percent to the Gross Domestic Product (GDP) out of which rice alone contributes 20.75 percent in agriculture GDP (ABPSD, 2014). The average productivity of rice in Nepal is 3.40 mt/ha. Despite being a major cereal crop, rice productivity is still low in Nepal. With the scenario of increasing population, rice demand (4,518 thousand tons) in Nepal is projected to be more than double the domestic production (2.512 thousand tons) by the year 2030. It is estimated that the domestic production of rice will be deficit by 79.9% (Prasad *et al.*, 2011). Nitrogen is an element most often required for the high yield of rice (Matsushima, 1976) of which deficiency generally results in stunted growth and chlorotic leaves and its presence in excess amount results dark green tissues of soft consistency and relatively poor root growth. Urea is the predominant source of nitrogen (N) in the rice fields but 70 percent of the applied nitrogen gets lost in the atmosphere and only 30 percent of it, gets used. Based on these conclusions, the concept of Site Specific Nutrient Management (SSNM) was developed for applying nutrients at optimal rates and times to achieve high yields and high efficiency of nutrient use by the crop.

Detailed studies evaluating the yield gap on-farm in rained lowland rice of the mid-hills and determining the different factors contributing to the yield gap are not available yet. Obviously, it is essential to reduce the yield gap from the innovative technologies because the country's target is to achieve over 5 million tons by the year 2020 to be self-sufficient in rice production (Joshy, 1997).

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MATERIALS AND METHODS

1. THE STUDY AREA

An experiment was conducted in farmers' field of Mahadevsthan of Kavrepalanchok to determine the performance of rice at various means and quantity of nutrients at irrigated condition during July to November, 2016 to assess the growth phenology and yields of hybrid rice. The experiment was carried out in farmers' field of Mahadevsthan VDC of Kavrepalanchok district from June to November, 2016.The site is located at 270 71' North latitude and 85° 61' East longitudes which is 670 meter above sea level.

2. CHARACTERISTICS OF THE SOIL IN EXPERIMENTAL FIELDS

Composite soil samples were randomly taken from different spots from 0–15 cm depth using tube auger for the soil physico-chemical properties. The samples were air dried, ground and sieved through 2 mm sieve and total nitrogen, available potassium, pH and organic matter were analyzed in the laboratory.

3. WEATHER RECORD OF THE EXPERIMENTAL SITE

Meteorological data such as maximum-minimum temperature, relative humidity and rainfall amount was collected from July to November 2016, from CEAPRED meteorological station of Mahadevsthan, Kavrepalanchok.

4. LAYOUT OF EXPERIMENTAL FIELD

The field layout was done with Randomized Complete Block Design. 24 plots were prepared for 6 treatments and 4 replications as per the table below.

Table 1. Treatment details

Treatment number	Symbol	Treatment Combination
T_1	Jholmal	Liquid manure (Jhol Mal) (1360 litre/ha)
T_2	NE	Nutrient Expert recommended dose (Farmer 1: 141:39:72 kg NPK/ha, Farmer 2 – 132:38:61 kg NPK/ha, Farmer 3- – 132:38:61 kg NPK/ha and Farmer 4 – 132:38:61 kg NPK/ha
T_3	LCC	Nitrogen as per Leaf Color Chart (LCC) and P & K from Nutrient Expert
T_4	RDF	GoN recommended dose (140:60:30 kg NPK/ha) (Shah, 2013)
T_5	FYM	Farm Yard Manure (FYM) (15 ton/ha)
T_6	FFP	Farmers' existing practices (60.4:36.8:36 kg NPK/ha for farmer 1,= 71.2:64.4:0 kg NPK/ha for farmer 2, 45.08:36.8:0 kg NPK/ha for farmer 3 and 31.8:46:0 kg NPK/ha for farmer 4)

5. RAISING SEEDLINGS AND TRANSPLANTATION

The rice variety used in the experiment was Shankar hybrid. It is long grained medium duration varieties (Agropedia, 2009). The seedlings were raised in a single seed bed for all the replication. Seed bed was prepared 15 days prior to transplanting. The seed rate was 10 $kgha^{-1}$ and fertilizer dose @ 100:80:80 kg NPK ha^{-1} through urea (46% N), DAP (18% N and 46% P_2O_5) and MOP (60%

K_2O).The 15 days old seedlings were transplanted at 25 cm × 25 cm. One seedling per hill was used while transplanting.

6. FERTILIZER APPLICATION

For inorganic fertilizer, Urea (46% N) was a source of Nitrogen, Diammonium Phosphate (18% N and 46% P_2O_5) was a source of Phosphorus and MOP (60% K_2O) was a source of Potassium as per the government recommendation.

In the first treatment, The jholmal was prepared by decomposing cow-dung and urine. It is applied @ 1360 litre/ha. The jholmal was diluted in 1: 3 ratios and application was started after 15 DAT and continues upto 75 DAT in 15 days of interval.

In the second treatment, fertilizer dose as per the recommendation of NE had been applied in all plot. With the data of surveyed questionnaire, the model was run and the model recommended the amount of fertilizer along with the application time.

In the third treatment, P & K was applied as per the recommendation made by NE and N was applied as per need on the basis of Leaf Color Chart (LCC) score.

In the fourth treatment, fertilizer in each plot was applied as per the recommendation by NARC;140:60:30 kg NPK/ha (Shah, 2013).

In the fifth treatment, FYM was applied to each field at 15 ton/ha.

In sixth treatment, a survey was done with designated questionnaire from the nutrient expert model. Based on the response of each farmer, fertilizer rate was calculated and applied accordingly.

7. DATA COLLECTION/OBSERVATIONS TAKEN

Plant height: 10 hills from the plot were selected at an interval of 15 days from (30-90) DAT and one at harvesting time.

Number of tillers: Sample of two hills from each plot was taken at 15 day interval after 30 DAT.

Length of panicle: The length of panicle was taken from 20 randomly selected panicles and mean was calculated

Harvest Index: Harvest index (HI) was computed by H.I. % = (grain yield × 100)/(grain yield + straw yield)

Economic analysis: B:C ratio was calculated by using gross return and cost of cultivation (Basnet, 2000); Benefit: cost ratio= Net return / cost of cultivation

8. STATISTICAL ANALYSIS:

All the recorded data were entered, processed and analyzed by using MS excel and MSTAT-C.

RESULTS AND DISCUSSION

1. EFFECT OF NUTRIENT MANAGEMENT PRACTICES ON PLANT HEIGHT OF RICE

The ANOVA showed significant differences among treatments for plant height at 30, 75, 90 DAT and at harvest correspondingly both at 0.05 and 0.01 level of significance. Non-significant differences were observed for plant height at 45 and 60 DAT (Table 2). At 30DAT, NE management had significantly highest value (44.28cm) for plant height followed by Jholmal application (44.25cm) and LCC based management (41.98cm). Lowest value was found in RDF (38.55cm). Non-significantly tallest plants were reported in FFP (67.15 and 87.10cm) at 45 and 60 DAT while shortest plants were observed in Jholmal application (61.21 and 79.20cm).

Table 2. Effect of nutrient management practices on plant height of rice at Kavrepalanchowk

Treatments	Plant height (cm)					
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	At harvest
Jholmal	44.25^{a}	61.12	79.20	97.42^{c}	105.25^{c}	114.53^{b}
NE	44.28^{a}	63.30	82.43	100.35^{bc}	108.50^{bc}	118.75^{a}
LCC	41.98^{ab}	64.67	81.55	102.15^{abc}	110.45^{ab}	117.80^{ab}
RDF	38.55^{c}	65.58	85.98	106.67^{a}	113.47^{a}	120.50^{a}
FYM	42.02^{ab}	67.05	84.88	103.38^{ab}	111.38^{ab}	118.05^{ab}
FFP	40.33^{bc}	67.15	87.10	104.47^{ab}	111.85^{ab}	119.07^{a}
Grand mean	41.90	64.81	83.50	102.41	110.15	118.12
SE±d	1.29	2.46	3.59	2.13	2.10	1.61
LSD (0.05)	2.75	5.24	7.65	4.54	4.47	3.44
CV (%)	4.30	5.40	6.10	2.90	2.70	1.90
F-test	**	ns	ns	**	*	*

** Significant at 0.01 level of significance, * Significant at 0.05 level of significance Means with the same letter are not significantly different

At 75 DAT, RDF recorded significantly tallest plants (106.67cm) followed by FFP (104.47cm) and FYM (103.38cm). The plant height of rice on LCC (110.45cm), FYM (111.38cm) and FFP (111.85cm) was statistically at par with RDF (113.47cm) at 90DAT. Similarly, significantly tallest plants were observed on RDF (120.50cm) at harvest. The FFP (119.07cm), NE (118.75cm), FYM (118.05cm) and LCC (117.80cm) management had statistically similar plant height at harvest. The dwarf plants were found on Jholmal application (97.42cm at 75 DAT, 105.25cm at 90DAT and 114.53cm at harvest).
For all the nutrient management practices, the plant height was increased with increase rate till 75 DAT and then increased with decrease rate upto harvest stage.

2. EFFECT OF NUTRIENT MANAGEMENT ON NUMBER OF TILLERS/M2 OF RICE

The ANOVA showed significant effects of different nutrient management practices on no. of tillers/m^2 of rice at 30, 75, 90 DAT and at harvest at 0.05 level of significance Trends of plant height of rice as affected by nutrient management while it was non-significant at 45 and 60 DAT (Table 3). At 30 DAT, significantly more number of tillers/m^2(265.20) was obtained on Jholmal applied field while others treatments showed statistically similar results and significantly lowest number of tillers/m^2 was in RDF (158.80). Non-significantly highest number of tillers/m^2 (335.60) was reported in RDF followed by LCC (324.40), FYM (307.60) and so on at 45 DAT. The lowest value was in Jholmal (273.20). Likewise, non-significantly more number of tillers/m^2 (438.40) was found in LCC and then in RDF (388.00), NE (386.00) and so on also at 60 DAT. The less number of tillers/m^2 was in Jholmal (367.60). At 75 DAT, significantly highest number of tillers/m^2 was reported in LCC (416.20). The number of tillers/m^2 of RDF (387.90) was at par with LCC. Significantly lowest number of tillers/m^2 was found in Jholmal (354.80) which was statistically similar with FFP, FYM and NE. Statistically significant number of tillers/m^2 was obtained in LCC (387.65) which is statistically at par with RDF (386.40) at 90DAT. The significantly less number of tillers/m^2 was reported in Jholmal (330.00). At harvest, significantly highest number of effective tillers/m^2 (278.40) was recorded in RDF followed by LCC (273.00), NE (264.40) and FYM (262.40). The significantly lowest number of effective tillers/m^2 (224.80) was in FFP at harvest.

The reduction of tiller number per plant at later growth stage might be due to tiller mortality under intra plant competition for growth resources. These results are in agreement with those obtained by Maclen (2010).

Table 3. Effect of nutrient management practices on number of tillers/m^2 of rice at Kavrepalanchowk

Treatments	No. of tillers/m^2					
	30DAT	**45DAT**	**60DAT**	**75DAT**	**90DAT**	**At harvest**
Jholmal	265.20^{a}	273.20	367.60	354.80^{b}	330.00^{b}	247.60^{ab}
NE	209.20^{b}	291.60	386.00	376.40^{b}	355.20^{ab}	264.40^{a}
LCC	177.20^{b}	324.40	438.40	416.20^{a}	387.65^{a}	273.00^{a}
RDF	158.80^{b}	335.60	388.00	387.90^{ab}	386.40^{a}	278.40^{a}
FYM	197.20^{b}	307.60	383.60	375.60^{b}	365.10^{ab}	262.40^{a}
FFP	200.80^{b}	299.20	379.20	371.60^{b}	357.60^{ab}	224.80^{b}
Grand mean	201.40	305.00	390.50	380.40	363.70	258.40
SE±d	26.28	40.50	26.76	15.51	17.22	15.60
LSD (0.05)	56.01	86.40	57.04	33.07	36.70	33.25
CV (%)	18.50	18.80	9.70	5.80	6.70	8.50
F-test	*	ns	ns	*	*	*

** Significant at 0.01 level of significance, * Significant at 0.05 level of significance

Means with the same letter are not significantly different

The response of nutrient management practices within the growth period was mixed; however, across the growth period was in similar pattern. In all nutrient management practices the number of tillers/m^2 were found to be increased in speed till 60DAT and the rate was negligibly decreased to 90 DAT and sharply reduced at harvest. This shows there was occurrence of tiller mortality after maximum tillers attained by rice. This mortality is might be due to heavy competition among the tillers of rice for resources particularly nutrients and water.

3. EFFECTS OF NUTRIENT MANAGEMENT PRACTICES ON YIELD AND YIELD COMPONENTS OF RICE

3.1. Panicle length

The ANOVA showed significant effects of treatments on the panicle length of rice at 0.01 level of significance (Table 4). The significantly longer panicle (28.19cm) was observed in FFP followed by NE management (28.16cm). The RDF (26.91cm) and LCC (26.90cm) had statistically similar panicle length. The Jholmal extruded significantly shortest panicle (26.36cm).

Table 4. Effect of nutrient management practices on yield and its component characters of rice at Kavrepalanchowk

Treatments	Yield components							
	Panicle length (cm)	Panicle weight (g)	No. of grains/ panicle	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)	Sterility (%)
Jholmal	26.36^{c}	3.10^{bc}	217.20^{c}	16.75^{ab}	4.83^{ab}	9.75^{bc}	32.88^{ab}	16.00^{bc}
NE	28.16^{a}	3.83^{a}	269.80^{a}	17.50^{a}	5.84^{a}	10.27^{abc}	37.32^{a}	16.50^{abc}
LCC	26.90^{b}	3.43^{b}	273.80^{a}	16.50^{b}	5.61^{a}	9.52^{c}	37.17^{a}	14.75^{c}
RDF	26.91^{b}	3.00^{c}	240.00^{bc}	15.50^{c}	5.14^{ab}	11.47^{ab}	31.17^{ab}	17.75^{abc}
FYM	26.56^{bc}	3.15^{bc}	239.20^{bc}	14.00^{d}	4.10^{b}	11.18^{abc}	26.96^{b}	20.00^{ab}
FFP	28.19^{a}	3.38^{b}	248.20^{ab}	15.50^{c}	5.21^{ab}	12.04^{a}	30.32^{b}	20.75^{a}
Grand mean	27.18	3.31	248.00	15.96	5.12	10.70	32.64	17.62
SE±d	0.20	0.16	12.24	0.41	0.49	0.81	2.76	1.88
LSD (0.05)	0.43	0.34	26.10	0.87	1.05	1.72	5.89	4.02
CV (%)	1.10	6.90	7.00	3.60	13.50	10.70	12.00	15.12
F-test	**	**	**	**	*	*	*	*

** Significant at 0.01 level of significance, * Significant at 0.05 level of significance

Means with the same letter are not significantly different

3.2. Number of grains/panicle

The ANOVA displayed significant effects of treatments on number of grains/panicle of rice at 0.01 level of significance (Table 4). The significantly maximum number of grains/panicle (273.80) was reported in LCC followed by NE management (269.80) and FFP (248.20). The RDF (240.00) and FYM (239.20) had statistically at par number of grains/panicle. The significantly lowest number of grains/panicle (217.20) was found in Jholmal.

3.3. Test weight

The ANOVA highlighted significant effects of treatments on test weight of rice at 0.01 level of significance (Table 4). The NE management had significantly pounded thousand grains weight *i.e.* test weight (17.50g) compared to others. The Jholmal had second weighted thousand grains (16.75g) and then in LCC (16.50g). The RDF (15.50g) and FFP (15.50g) had statistically similar weight of thousand grains. The significantly lightest weight of thousand grains (14.00g) was in FYM.

3.4. Grain yield

The ANOVA elucidated significant effects of treatments on grain yield of rice at 0.05 level of significance. The significantly higher grain yield (5.84tha-1) was recorded in NE management followed by LCC (5.61tha-1), FFP (5.21tha-1) and RDF (5.14tha-1). The significantly lowest yield (4.10tha-1) was obtained in FYM. The yield is a complex traits attributed by different components. The highest yield in NE management is due to significantly highest value of panicle length, number of grains/panicle, test weight, harvest index, dry matter accumulation, number of effective tillers and maximum LAI.

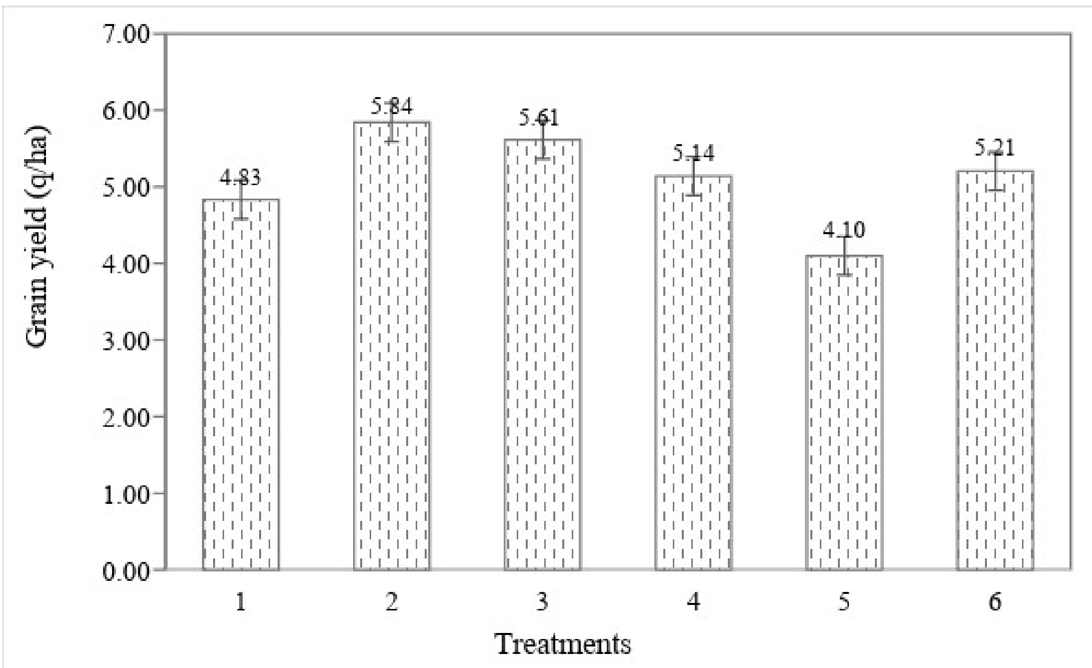

Figure 1. Effect of nutrient management practices on grain yield of rice

A higher N rate at panicle initiation could increase spikelet per panicle, and consequently, increase grain yield for a variety with small panicle size (Wang, 2002). Based on field experiments conducted in Zhejiang, Canton, Hunan, Jiangsu, Hubei and Heilongjiang provinces in China, SSNM reduced N fertilizer use by 32% and increased grain yield by 5% compared with farmers' usual fertilizer practices (Peng *et al.*, 2006).

3.5. Harvest index

The NE management had significantly highest harvest index (37.32%) compared to others. The seconds highest harvest index was recorded by LCC (37.17%) and then by Jholmal (32.88%) and RDF (31.17%). Significantly lowest harvest index (26.96%) was found in FYM which was at par with FFP (30.32%).

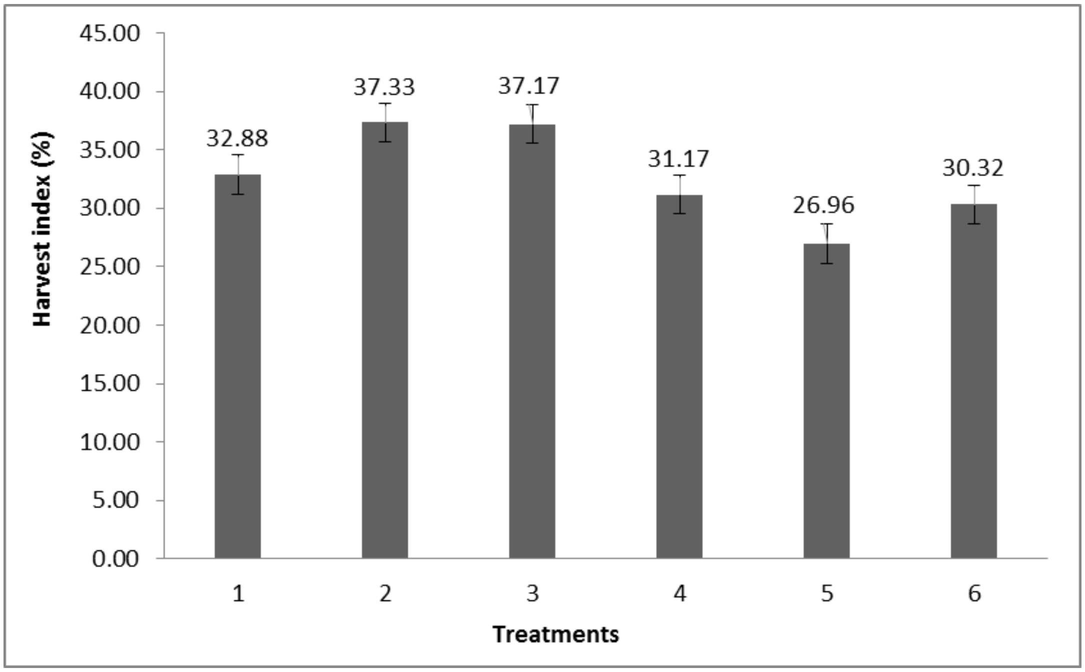

Figure 2. Effect of nutrient management practices on harvest index of rice

3.6. Yield Gap Analysis

The grain yield obtained varied significantly with the treatments. The significantly higher grain yield (5.84tha-1) was recorded in the treatment with nutrient management using NE followed by LCC (5.61tha-1), FFP (5.21tha-1) and RDF (5.14tha-1). The significantly lower yield (4.10tha-1) was obtained in FYM plot which was 12.09% lower than that achieved in NE as compared to FFP.

3.7. Production economics

3.7.1. Fertilizer cost

The fertilizer cost differed significantly among the treatments. The fertilizer cost was higher in *Jholmal* (NPR 54400 ha-1) followed by FYM (NPR 54400 ha-1) and lowest in NE, LCC and RDF Where statistically least fertilizer cost is in Farmers Field Practice. All in all, the cost of organic fertilizer is higher as compared to the inorganic fertilizer. The fertilizer cost for FYM and Jholmal are calculated on the basis of informal survey from key informants and market.

Table 5. Fertilizer cost, cost of cultivation, gross return, net return and B:C ratio of rice influenced by nutrient management practices in Mahadevsthan, Kavrepalanchowk, Nepal during 2016.

Treatment	Fertilizer cost(NRs)	Total cost	Gross return	Net return	B:C ratio
Jholmal	54400a	159365a	140148ab	-19217b	0.878c
NE	14580c	118195cd	182710a	64516a	1.545a
LCC	14878c	119392c	161936ab	42543a	1.356a
RDF	13737c	117309c	149646ab	32338ab	1.275ab
FYM	30000b	133165b	120295b	-12869b	0.903bc
FFP	7747d	111362d	151859ab	40497a	0.879a
SEm(+/-)	383.1	383.1	11484.6	11373.3	0.085
LSD(0.05)	154.7**	1154.7	34618.4*	34282.8	0.256**
CV(%)	3.4	0.6	15.2	92.3	14
Grand mean	22557	126465	151099	24635	1.221
F-value	<0.001	<0.001	0.032	<0.001	<.001

*** Significant at 0.01 level of significance, * Significant at 0.05 level of significance*
Means with the same letter are not significantly different

3.7.2. B/C Ratio

NE has highest gross return of NPR 182710 ha-1 whereas FYM has lowest gross return of NPR 151859 ha-1. Whereas, higher cost was in Jholmal (NPR 159365 ha-1) and lowest cost of cultivation was in FFP (NPR 111362 ha-1). NE (1.545) recorded the highest B:C ratio followed by LCC (1.356) and then FFP (0.879) but all three are statistically at par. While lowest B:C ratio was recorded in Jholmal (0.878). This Higher B:C ratio in NE treatments might be due to N saving and increased yield of crop which ultimately increased gross and net return and reduced production cost. Sharma (1991), reported the increase net return and B:C ratio in LCC based N management.

CONCLUSION AND RECOMMENDATION

The NE management produced significantly higher thousand grain weight *i.e.* test weight (17.50g) with significantly higher grain yield (5.84tha-1) and harvest index (37.32%) followed by LCC whereas significantly higher straw yield (12.04tha-1) was found in FFP. This study suggests that, It is necessary to expand on-farm demonstration of improved N management technologies to all rice areas to convince the farmers, researchers and government officials that yields, profit and N use efficiency can be easily improved through better nutrient management practice

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CLIMATE CHANGE IMPACTS ON AGRICULTURE AND LIVESTOCK IN NEPAL

Shree Bhagavan Thakur[1] and Gyanendra Karki [2]

ABSTRACT

Agriculture is the main stay of Nepal's economy and is highly vulnerable to climate change due to climate variability, climate-induced hazards and risks of the natural disasters. Large proportion of marginal farmers with small landholding, limited irrigation, low income level, limited institutional capacity, and greater dependency of agriculture on climate-sensitive natural resources has accelerated vulnerability. Climate change has observed effects on phenology of plants and breeding behavior of animals. This will likely affect production and productivity of agriculture and livestock from increased pest and disease infestation, and land degradation. It will further impact on soil fertility, animal fertility and behavior, and quality and quantity of food, feed and fodders, and biodiversity. Ultimately, higher cost of production and price of commodity is adversely affecting farm revenue, employment, income and finally on GDP. Insights on the climate change impacts on agriculture and livestock will help to various stakeholders to advance response mechanisms, including through policy, plan and strategy.

Key words: Agriculture, climate change, impacts, livestock and vulnerable

INTRODUCTION

Nepal is one of the most climate vulnerable countries both by virtue of its rogued and mountainous topography and the socio-culturally embedded poverty coupled with its status of Least Developed Country. The countries with the most risks are characterized by high levels of poverty, dense populations, exposure to climate-related events, and their reliance on flood and drought-prone agricultural land (Maplecroft, 2012). Agriculture in Nepal is highly vulnerable to climate change due to climate variability and related risks of natural disasters. Large proportion of marginal farmers with small landholding, limited irrigation, low income level, limited institutional capacity, and greater dependency of agriculture on climate-sensitive natural resources increase the degree of vulnerability (Regmi and Adhikari, 2007).

Climatic variables projected by Organization for Economic Co-operation and Development (OECD) based on General Circulation Model (GCM) estimated that the mean annual temperature is likely to increase by an average of 1.2^{0}C by 2030, 1.7^{0}C by 2050 and 3^{0}C by 2100 compared to a pre-2000 baseline along with Special Report on Emission Scenarios (SRES B2) scenario. Likewise, Regional Circulation Models (RCM) project the mean annual temperature to increase by 1.4^{0}C by 2030, 2.8^{0}C by 2060 and 4.7^{0}C by 2090 (NCVST, 2009).

OECD projected almost no change in winter precipitation in western Nepal and up to 5-10% increase in eastern Nepal. However, it projected an increase in precipitation for the whole country in the range of 15 to 20% during summer. NCVST, 2009 projected an increase in monsoon rainfall in eastern and central Nepal as compared to western Nepal but an increase in monsoon and post-monsoon rainfall as well as an increase in the intensity of rainfall, and a decrease in winter precipitation. The

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overall annual precipitation may be decreasing by 2 % of the baseline amount by 2020s. However, it increases by 6 % and 12 % of the baseline by 2050s and 2080s respectively (MoSTE, 2014b).

Agriculture is affected most when drought adversely impacts rain-fed agriculture, largely in developing countries where the majority of farmers practice subsistence agriculture. In terms of agriculture and food security, local communities have identified changes in climate as being largely responsible for declining crop and livestock production. Nepal's vulnerable subsistence farming economy is facing risk due to changes in stream flow, a more intense and potentially erratic monsoon rainfall, and flooding (JVS/GWP, 2015).

This paper collates data and information on major climate change impacts on agriculture and livestock to inform policy-makers, development workers, climate change advocates and producers to take into account the measures to help climate vulnerable to adapt to, and build resilience to climate change impacts.

METHODOLOGY

This study is based on rigorous review of climate change and agriculture related pertinent documents that were brought forth in Nepal's NAP process. It included but not limited to climate change convention related documents, national policies and strategies including plans and programmes, legal documents, published reports, journal articles, literatures and research papers. The information was drawn from national and international sources and they were critically scanned, skimmed, reviewed, shorted and analyzed for this study. This study was done from June 2016 to November 2016.

RESULTS AND DISCUSSIONS

Global warming and climate change are the greatest concerns since they affect human beings and the whole ecosystem. Its impact on agriculture is more pronounced and easily understood as agro-sector is more dependent on nurture. In Nepal, early symptoms of climate change due to alarmingly increased temperature have been observed. Furthermore, Nepal was experienced sufficiency in paddy production and it has turned to a rice importer from an exporter till 1980s. Likewise, the Sustainable Development Goal (SDG)[3] and Agriculture Development Strategy (ADS)[4] 2015–2030, reported that Nepal faces food grains deficit in more than 13 districts in the hill and high hill regions.

Crop and livestock farming, in different combination, are major way of life in the communities. Cereal crops including rice, wheat, maize, millet, barely and buckwheat is the mainstay of Nepal's agriculture. These crops are greatly affected by weather variability including drought. The impacts, though expected to become higher in the mountains compared to low lying Tarai region, are detrimental to both regions and ultimately to agricultural production, food security and the people's economy. Moreover, agriculture sector performance depends mainly on conducive weather

3 Goal 2 of SDG focused "End hunger, achieve food security and improved nutrition and promote sustainable agriculture" by 2030.

4 Emphasized to accelerate agricultural sector growth through four strategic components viz. governance, productivity, profitable commercialization, and competitiveness by 2030.

conditions, and the agrarian poor community suffers most from any adverse situation brought about by climate change (MoE, 2010a).

IMPACTS OF CLIMATE CHANGE ON AGRICULTURE

Agriculture is the mainstay of rural food and economy that accounts for about 96% of the total water use in the country - suffers a lot from erratic weather patterns such as heat stress, longer dry seasons and uncertain rainfall, since 64% of the cultivated area fully depends on monsoon rainfall (CBS 2006). Declined yield due to unfavorable weather and climate will lead to vulnerability in the form of food insecurity, hunger and shorter life expectancies (Ebi *et al*. 2007), and the rural poor will again be the hardest hit. Floods carrying rocks, sediments and debris increase the intensity of landslides and erosion; deteriorate soil and water quality; wash away houses and properties; cause human injuries and deaths; destroy infrastructure such as schools, roads, and markets (Chaudhary and Aryal, 2009).

In Nepal, losses have occurred in agricultural sector due to climatic events (Tables 1 and 2) in the past four decades

Table 1. Loss of agricultural land as a result of climate-related extreme events in Nepal (1971-2007)

Events	Loss (in hectares)
Drought	329332 (38.85%)
Flood	196977 (23.25%)
Hailstorm	117518 (13.86%)
Rains	54895 (6.47%)
Strong wind	23239 (2.74%)
Cold waves	21794 (2.57%)
Others (forest epidemic, snow storm, fire, storm, etc.)	83336 (9.83%)
Total	847648

Source: IFAD (2013)

The highest loss of land was from drought (38.85%) followed by flood (23.25%), hailstorm (13.86%), rains (6.47%), strong winds (2.74%) and cold waves (2.57%). It is likely that a variety of climate-induced threats will extend the impacts in new areas. Rapid population growth, shrinking farm size in the Terai Region and continued unplanned agriculture in hazard-prone areas are expected to add to the damage and losses if no counter measures are put in place timely. The cropping intensity in climate vulnerable areas is increasing because of demand for food.

Table 2. Affected crop area from climate-related extreme events in Nepal (In hectare)

Crops	Year							
	2002	2003	2004	2005	2006	2007	2008	2009
Paddy	115000	6967	116506	3585	120000	88800	30873	92000
Maize	4 435	954	1293	20	47	4271	549	1700
Millet	-	-	500	419	-	1451	3	-
Others	2067	611	-	-	-	-	324	-
Total	*121502*	*8532*	*118299*	*4024*	*120047*	*94522*	*31749*	*93700*

Source: IFAD (2013)

International Food Policy Research Institute (IFPRI) also assessed impacts of climate change on global cereal production and concluded that negative impact of climate change on world cereal production may vary from 0.6% to 0.9%, but that in South Asia, the impact could be as high as 18.2% to 22.1% (Von Braun, 2007). Within South Asia, impacts are more pronounced in mountain areas than in the plains. It means, impacts of the climate change are high in Nepal. On contrary, some experiments have shown opposite results, increasing crop yield particularly rice and wheat with increase in climate variables (Malla, 2008). However, the findings of this study show the net negative effect (MoSTE, 2014b).

Decline in rainfall from November to April has adversely affected the winter and spring crops. Impacts of climate change on agriculture are in major multidimensional and intricately vicious as 'agriculture' is a function of several biotic and abiotic factors. Climate change will likely affect various components in a location-specific system of agriculture through its impacts in biophysical and socio-economic factors with ultimate negative effects on farm productivity. Positive impacts of climate change are also predicted on crop and animal production (Gautam and Pokhrel, 2010).

The perceived impacts on agriculture were decreased crop yield, reduced soil moisture, and increased incidence of new pests and invasive plant species. Such impacts were fairly heterogeneous in distribution. The Salyantar village of Dhadhing, a raised flat-land of river deposition already stuck in the grip of water stress, was found exacerbated by the effect of climate change (Paudyal *et al*. 2015).

The major impacts speculated in crop husbandry are declining availability of water for agricultural uses, hindrance in operation of conventional irrigation systems and decreasing water use efficiency, increasingly degrading agricultural land, increasing depletion of land from agricultural uses, diseases and pest epidemics and increasing crop management risks. Those associated with poor availability of quality planting materials and technologies, catering changing context needs, are foreseen to affect crop production and economic sustenance of farmers adversely (MoE, 2010b).

Many studies have attempted to estimate impacts of climate change on agriculture mostly by combining crop growth models with economic models. The climate change has potential impacts on costs of production, farm revenues, farm value, employment, income, consumption, and finally on the GDP. Though several studies have been done on the effects of climate change on crop production mostly using crop simulation models based on different scenarios of GHG emissions, temperature rise and risks of extreme events, but the studies on the costs to the farmers are very limited. Effect of climate change on crop productivity is particularly sensitive because of its strong linkage with food security.

An economic Assessment of Climate Change in Key Sectors has estimated direct cost of current climate variability and extreme events equivalent to 1.5 to 2 % of current GDP/year (approximately USD 270-360 million/year in 2013 prices) and much higher in extreme years (MoSTE, 2014a).

Projection has shown that the net decrease in rice production will be 51 thousand metric tons in 2020; 216 thousand metric tons in 2050 and 412 thousand metric tons in 2080. The decrease in 2020 is 1.6% of the present production, that in 2050 is 6.7% of the present production and in 2080 12.9% of the present production. Likewise, with the mixed effects of temperature and precipitation, the wheat production in the main wheat growing areas is projected to decrease by 176 thousand tons in

2020, a small increase of 64 thousand metric tons in 2050 and a decrease of 111 thousand metric tons in 2080. The projected changes in production is equivalent to a 15.5% decrease in 2020, 5.6% increase in 2050 and 9.7% decrease in 2080 in terms of present level of production. Everything else remaining the same, the national loss in food production is expected to be 5.3% in 2020, 3.5% in 2050 and 12.1% in 2080. The loss of food grain thus accounts to 435 thousand metric tons in 2020, 302 thousand metric tons in 2050 and 1040 thousand metric tons in 2080 (MoSTE, 2014).

CO_2 concentration causes partial closure of stomata, which reduces water loss by transpiration and thus improves water-use efficiency (Rotter and van de Geijn, 1999). Other things remaining equal, this leads to improved crop yield, even in conditions of mild water stress. The effect is much larger for C3 plants (rice, wheat, tomato), but there is also a small effect for C4 plants like maize, sorghum, sugarcane. Effects on yield, biomass and photosynthesis have been demonstrated in many studies using growth chambers, and a recent review by Long *et al*. (2006) indicates that yield increases for several C3 crops may be of the order of 20–30% at elevated CO_2 concentrations of 550 ppm. Tubiello *et al*. (2007) vigorously defend the data from enclosure experiments (and the crop model developments that were built on their foundation).

They also suggest that lower crop responses to elevated CO_2 of the magnitudes in question would not significantly alter projections of global food supply (Tubiello *et al*., 2007), although the effects at more local scales may be more important in the context of food security. The AR4 gives figures of 10–25% yield increases under unstressed conditions for C3 crops, and 0–10% increases for C4 crops, at 550 ppm atmospheric CO_2 concentrations.

The climate change affects the food security adversely at all four levels—global, national, household and individual. It is realized that among the climate parameters, the rise in minimum temperature reduces yield of rainy season crops affecting national self-sufficiency of food grains. The climate change affects the entire food system from production, processing, distribution, consumption and utilization. Food security in Nepal is particularly vulnerable to climate change due to low level of human control over the water and temperature and fragile ecosystems that get easily affected from the climate change and related extreme weather events (Pant, 2012).

IMPACTS OF CLIMATE CHANGE ON LIVESTOCK

Global warming has remarkable effects on the phenology of plants and the breeding behavior of animals that are highly sensitive to photoperiod and heat. Several studies have confirmed the change in breeding habits (e.g. courtship calling, birthing, mating, bird singing) in animals and insects, and in the blooming and flowering time of plants, from a few days to as early as a month before historical precedents (Hersteinsson and MacDonald 1992, Grabherr *et al*. 1994, Parmesan 1996, Groom *et al*. 2006).

The declining forage production in natural pasture due to poor emergence of grasses, pastoral degradation and invasive species, increasing prevalence of animal parasites and vector-borne and parasitic diseases, heat stresses especially in pig, eroding breeds of sheep and pig, transhumance system loss, changes in animal reproductive behavior especially in terms of heat-period and fertility, shortage of feed ingredient and increased production/emission of GHGs due to animal health reasons have been major impacts and concerns of climate change in animal husbandry. It has also been foreseen the outbreak of feed toxicity, nutritional diseases and poor health in farm animals resulting in higher mortality rate, increasing production costs and low productivity as consequences of the impacts thereby affecting animal herders' livelihood (MoSTE, 2014a).

There is a growing concern on the effects of the climate change on livestock production. Dixon *et al*. (2003) noted that there are likely to be smaller impacts on livestock yields *per se*, compared with grassland biomass, because of the ability of livestock to adjust consumption in response to the changes. There is still another type of reporting that the net revenues from livestock for small farmers will be up by 25 %, and that for large farmers goes down by 22 % (Seo and Mendelsohn, 2006). This is due to increased market price to all the farmers and increased costs of production to the large farmers. On contrary, several studies (SCA, 1990) show that the climate change adversely affects livestock and poultry production.

Livestock production is highly sensitive to climate change and that there is a non-linear relationship between climate change and livestock productivity (Kabubo-Mariara, 2009). Rising temperature increases lignification of plant tissues and reduces the digestibility (Minson, 1990), reducing meat and milk production in range-based livestock production system. Increased heat stress is another pathway affecting the livestock production. The increased heat alters heat exchange between animal and environment affecting the feed intake and metabolism (SCA, 1990. Such stresses will affect growth and productivity of the animals. But, effects vary from species to species. For example, water buffaloes need frequent bath for heat exchange. Drying of ponds due to drought can deprive the buffaloes for taking baths affecting adversely the productivity of the buffaloes. Similarly, the increased energy deficits may decrease cow fertility, fitness, and longevity (King *et al*., 2006). Increased temperature and humidity will increase the risks of mortality and morbidity among the livestock and poultry. Amundson *et al*. (2005) also reported a decline in conception rates of cattle (*Bos taurus*) for temperatures above 23.4°C. But, it is also suggested that impacts of heat stress may be relatively minor for the more intensive livestock production systems where some control can be exercised over the exposure of animals to climate change (Rotter and van de Geijn, 1999). It means that the loss in the livestock production depends on the degree of control of the shed. As the developed countries can control the livestock production conditions minimizing the losses from the climate change, the global price for the livestock products may not increase much due to the climate change. Thus, Nepalese livestock farmers who cannot control the production conditions of the livestock are bound to suffer from the both, reduced production and inadequate rise of the price.

Climate change also increases mortality and morbidity of animals particularly from the climate sensitive infectious diseases (Patz *et al*., 2005-). Increases in zoonotic diseases among the animals also increase the risks of transmission of such diseases in the human being. In summary, as a result of the climate change, Nepalese farmers have to bear loss from the livestock production (Pant, 2011).

Climate change impacts will include: reduction in the productivity of rain-fed crops used for livestock and poultry feed; reduction in productivity of forage crops; reduced water availability and more widespread water shortages; and changing severity and distribution of important human, livestock and crop diseases. Major changes can, thus, be anticipated in livestock systems, related to livestock species mixes, crops grown and feed resources and feeding strategies (Thornton *et al*. 2009). Such changes increase the costs of livestock production. The climate change is feared to have impacts on feed crops and grazing systems, for example, greater incidences of droughts can decrease fodder production and rise in temperate can change the species-mix in the pasture (Hopkins and Del Prado, 2007). Increase in the temperature changes the rangeland species distribution, composition, patterns and biome distribution (Hanson *et al.*, 1993) increasing the need for feed supplements. With the climate change, the cost of water for the livestock farming will increase. The livestock need water daily and frequently and also for animal feed production. But, the literatures on the added water costs for livestock production are not readily available. The climate changes also increase the costs of veterinary medicines in livestock and poultry production. Though the impacts of the climate change on animal diseases and their vectors depend on the ecosystems and their changes, nature of the pathogen and the susceptibility of the livestock (Patz *et al.*, 2005-), the cost of the treatment is likely to rise. The effects of climate change on the health of livestock and poultry are reported by many studies (Harvell *et al.*, 1999, 2002; Baylis and Githeko, 2006). Increased temperature and relative humidity also increases the risks on aflatoxin development in feed stuffs increasing the risks of poisoning among the animals (Pant, 2011). Thus, the climate change will increase the costs of livestock and poultry production and the subsistence farmers are always losers. However, the loss in the gross revenues from the livestock is expected to be smaller than those from the crops.

IMPACTS ON QUANTITY AND QUALITY OF FEEDS

Climate change can be expected to have several impacts on feed crops and grazing systems, including the following (Hopkins and Del Prado, 2007):

Changes in herbage growth brought about by changes in atmospheric CO_2 concentrations and temperature; changes in the composition of pastures, such as changes in the ratio of grasses to legumes; changes in herbage quality, with changing concentrations of water-soluble carbohydrates and N at given dry matter (DM) yields; greater incidences of drought, which may offset any DM yield increases and; Greater intensity of rainfall, which may increase N leaching in certain systems.

Nepalese livestock farmers who cannot control the production conditions of the livestock are bound to suffer from the reduced production and inadequate rise of the price. Climate change also increases mortality and morbidity of animals particularly from the climate sensitive infectious diseases. Increases in zoonotic diseases among the animals also increase the risks of transmission of such diseases in the human being.

The high hill animal herders, however, shared that climate change has declined fodder and forage production instead it has aggravated the prevalence of parasites on animals. Discontinuation of local cattle breed from the western mountain is an evidence.

CONCLUSION

The impacts of climate change on agriculture and livestock are very complex compared to other sectors. As agriculture is the main stay of the Nepal's economy which as adversely impacted due of climate change. It has negative impacts on crop and livestock production and productivity, pest and disease infestation, land degradation, soil fertility, animal fertility and behavior, quality and quantity of food, feeds and fodder, biodiversity, gene pool and others. It resulted in increased cost of production, price of food, and also added cost for irrigation facility, managing pest and diseases, etc. Agro-ecological extension of some crops due to temperature rise and increased number of warmer days, prevalence of livestock diseases and parasites and declines in fodder and forage productions in high mountains. The decreasing crop available soil moisture, crop failures and reduced crop productivity in middle mountains and Tarai, and climate-induced disasters rendering agricultural land uncultivable have become typical to Tarai (MoE, 2010b). Hence, the climate change affects the food security and livelihoods adversely at national, household and individual level. It will adversely affect farm revenue, employment, income and finally on GDP. However, it should not be ignored in any development effort due to its association with livelihoods of grassroots, social stability and well tracked development of other sectors. This paper will capitalize the impacts of climate change on the agriculture and livestock for adaptation planning for policy makers, development workers, climate change practitioners, researchers, and academia to response of the climate change.

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WEED SCIENCE RESEARCH AND ACHIEVEMENT IN NEPAL

Santosh Marahatta[1]

ABSTRACT

Nepal has a wide range of agro-climates and soil types and characterized by diverse farming systems resulted in different types of weed problems. Weeds cause crop yield losses up to 70% besides impairing product quality and causing health and environmental hazards. Problematic crop-specific weeds are emerging in these days. Manual weeding the traditional practice of weed control. Increasing labor shortage and costs encourage farmers to adopt alternative practices. Research on weed management is mostly focused on herbicide efficacy. Application of suitable pre-emergence followed by post-emergence herbicides is effective for controlling the weeds of the major crops rice, wheat and maize, which is beneficial even than the manual weeds. Tank mix applications are reported better than the sole applications. Brown manuring in rice is more effective than manual and herbicidal weed management options. Herbicides applied alone or in combinations, have been regarded as essential tools for effective management of weeds in different agro-ecosystems.

Keywords: Herbicide toxicity, weeds, weed dynamics, yield loss

INTRODUCTION

Weeds affect everyone in the world by reducing crop yield and crop quality, delaying or interfering with harvesting, interfering with animal feeding (including poisoning), reducing animal health, preventing water flow, as plant parasites, etc (Abouziena & Haggag, 2016). Weeds are the most acute pest in agriculture with an estimated annual global damage of around 40 billion dollars per year (Monaco et al., 2002). There is no reliable study of worldwide damage due to weeds. However, it is widely known that losses caused by weeds have exceeded the losses from any category of agricultural pests such as insects, nematodes, diseases, rodents, etc. The potential crop yield loss without weed control was estimated by 43%, on a global scale (Oerke, 2006). While Rao (2000) has reported that of the total annual loss of agricultural produce from various pests, weeds account for 45%, insects 30%, diseases 20% and other pests 5%. Annual worldwide losses to weeds were estimated to comprise approximately 10-15% of attainable production among the principal food sources (Abouziena & Haggag, 2016).

Reduction in crop yield has a direct correlation with weed competition. Generally, an increase in one kilogram of weed growth corresponds to a reduction in one kilogram of crop growth (Rao, 2000). Therefore, controlling weeds in fields is necessary to rise up yield quantity and quality, as well as minimize great losses in crop production resulting from weed-crop competition. That is an assumption that if all the weeds in food crops were controlled, the current world's food production would be higher by 10% to 25% (Rao, 2000). Weeds were considered the most important pest group even in the case of organic farming (Gianessi & Reigner, 2007). Worldwide consumption of herbicides represents 47.5% of the 2 million tons of pesticide consumed each year. However, the

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heavy use of herbicides has given rise to serious environmental and public health problems (Sopenaet al., 2009). Weed scientists are now facing new challenges, particularly in the light of the emergence of weeds resistant to herbicides and concerns and questions about herbicide residues in food, soil, groundwater-atmosphere (Abouziena & Haggag, 2016). The potential problems associated with herbicides use are (1) injury to non-target vegetation, (2) crop injury, (3) residues in soil and water, i.e., reduction of soil and water quality, (4) toxicity to other non-target organisms, (5) concerns for human health and safety and (6) herbicide-resistant weed populations (Li et al., 2003; Sunyata & Tosapon, 2010; Pot et al., 2011). Soil solarization, mulching, hot water, Fresnel lens, biological control, natural herbicides and some cultural treatments have been successfully tried and were found to be effective and safe methods to control weeds (Dang Khanh et al., 2005; Sahile et al., 2005;Lyse Benoit et al., 2006; Ramakrishna et al., 2006; Abouziena et al., 2008; Candido et al., 2011; Abouziena et al., 2015).This paper highlighted the major weed flora of the major cereals, their crop damage extent and important management strategies developed in different agro-ecology of Nepal.

MATERIAL AND METHODS

This paper has focused on weed science research with respect to the weed biodiversity and management practices on major cereal crops in Nepal and main data sources are from the literature that publish in the books and journals, and a few from the thesis. Other sources included the publications from outside of Nepal mainly for the background informations. Rice, wheat and maize were the top ranked crops in terms of cultivations, production and utilizations in Nepal, and also because their vital role in the national economy. The productions of these crops largely were influenced by the biotic as well as the abiotic factors which include the weeds. The major findings on the weeds science research in Nepal is documented in the present paper.

FINDINGS AND DISCUSSION

1. WEED HAVOC ON THE MAJOR CEREALS

Rice, maize and wheat contribute about 80% of the global cereal production and the share is equal in Nepal too. Weeds are undesirable plants, which infest different crops and inflict negative effect on crop yield either competition for water or nutrients or space or light. There are innumerable reports on the inhibitory effects of weeds on crop plants. Weeds are notorious yield reducers that are, in many situations, economically more important than insects, fungi or other pest organisms. Poor weed control is one of the major factors for yield reduction of rice depending on the type of weed flora and their intensity. About 32-42% yield reduction n various field crops has been reported due to weeds in Nepal (Ranjit *et al*., 2006).

2. WEED DIVERSITY OF THE MAJOR CEREALS

a. Rice

Weed species found in rice fields in Nepal are quite numerous and their presence may be seen throughout, though composition and density may vary in different ecological zones. These include grasses, non-grasses and sedges. In one of the old literature there are 207 weed species assigned to 51 families and 132 genera growing in association with rice in the country (Moody, 1986). About 52 species of weeds from 32 genera and 15 families form the transplanted rice field in central-hill having major weeds *Echinochloa colona, E. crusgalli, Cyperus iria* and *Ageratum conyzoides*

(Manandhar *et al.*, 2007). While slightly less diversity in weed density under dry-DSR (25 species, 21 genera and 15 families) was observed by Ranjit and Suwanketnikom (2003). The common weeds reported in direct seeding rice (DSR) were*Cyperus difformis, C. iria, Fimbristylis littoralis, Echinochloa colona, E. crusgalli, Paspalum distichum, Commelina diffusa, Monochoria vaginalis, Polygonum* sp.*, Dopatrium junceum, Lindernia* sp. and *Eclipta prostrate*. Bhatta *et al.* (2008) had found 46 species of weeds belonging to 34 genera and 18 families from upland and slightly lower from lowland (43 species, 32 genera and 17 families) ecology of western terai of Nepal. After 2 years study in weed diversity reported the increased number of weeds under both ecology (55 species from upland and 48 species from lowland). Bhatta *et al.* (2009) had reported the major weeds of rice under upland were *Fimbristylis miliacea, Lindernia oppositifolia, Eleocharis atropurpurea, Cyperus iria* and *Echinochloa crusgalli* and that of low land were *Eleocharis atropurpurea, Fimbristylis miliacea, Lindernia oppositifolia, Cyperus iria* and *Echinochloa crusgalli.* From the central terai of Nepal, Dangol *et al.* (1993) reported the total of 69 species of weed in 1986, 71 species in 1988 and 47 in 1992. The major weed species reported were *Echinochloa* spp.*, Hemarthria compressa, Fimbristylis* spp.*, Monochoria vaginalis, Alternenthera sessilis, Caesulia gyayanensis, Cyperus spp., Cynodon dactylon, Cammelia diffusa* and *Scirpus lateriflorus.* Similarly,*Caesulia axillaris*, *Amischophacelus axillaris*, *Cyperus difformis*, *Ceratopteris thalictroides, Fimbristylis miliacea and Echinochloa colona* were major weeds of rice grown in sandy loam texture soil of central terai (Dangol and Bhattarai, 1993). A total of 74 species belonging to 22 families were reported from western hill, among them *Ageratum conyzoides*, *Cynodon dactylon*, *Ischaemum rugosum*, *Echinochloa crusgalli* and *Cyperus rotundus* are considered more problematic (Thapa and Jha, 2005). *Cynodon dactylon, Echinochloa colonum, Commelina diffusa, Digitaria ciliaris, Eleusine indica* were major grassy weeds while *Cyperus rotundus, C. esculentus, Fimbristylis miliaceae* were major sedges and *Ageratum connyzoids* a broad leaf weed under SRI planted rice under irrigated upland of Chitwan (Pandey, 2009). Monocot weed species appeared along the early stage while dicot weed species were most dominant at later stages.At 21 DAT, *Cyperus esculentus* was found dominant weed species (40.53%), but at 42 DAT, *Commelina diffusa* (42.19%), *Cyperus esculentus* (38.92%) and *Ageratum connyzoids* (35.18%) were dominant at 63 DAT. At harvest *Commelina diffusa* (52.99%) and *Fimbristylis miliaceae* (34.76%) were dominant weed species.

b. Maize

Similar to the rice, weed species found in maize fields in Nepal are quite numerous and their presence may be seen throughout, though composition and density may vary with season of growing and ecological zones of cultivations. In central inner-terai region of Nepal 69 and 52 species of weeds belonging to 25 and 23 families were recorded during summer, respectively (Dangol and Gurung, 1989; Dangol *et al*., 1988). *Cyperus iria, Cyperus rotundus, Brachiaria ramose, Bulbostylis barbata, Dactylocetenium aegyptium, D. adscendens, Echinochloa colona, Commelina benghalensis, C. paludosa, Cassia tora, Eupatorium hirta, Erarostis tenella, Ageratum houstonianum, Phyllanthus urinaria* and *Melochia concatenate* were major weeds. The farmers of different area in mid-hills reported the violet wood sorrel (*Oxalis corymbosa*) problem in maize based cropping system since two decades. Result of two years experiment by KC (2007) indicated that the presence of violet wood sorrel in maize field was ranging from 18.60-352.30 per square meter.

c. Wheat

During the intensive study carried by Dangol (1993), 370 species of wheat weeds representing 54 families and 210 genera of vascular plants were reported in Nepal. Among the total families, 16 families include 5 or more species and this was accounted for 79.19% of the total weed species recorded. Two most dominant families were the Asteraceae and Poaceae which had 69 and 52 weed species, respectively with the best-represented genus *Polygonum* (15 spp.) followed by *Euphorbia* and *Stellaria* (8 spp. each), *Eragrostis*, and *Solanum* (7 spp. each), *Vicia* (6 spp.), and *Lindernia* and *Veronica* (5 spp. each). A survey conducted in wheat field by Chaudhary and Shrestha (1981) reported a large number of weeds in central hills of Nepal in association with wheat crops and the major weeds were *Cannabis sativa*, *Chenopodium album*, *P. minor* and *Vicia* spp. The common weeds in the experimental field of Khumaltar, Nepal during 2001/02 were *P. minor*, *Alopecuros* sp., *C. album*, *Stellaria media*, *Polygonum hydropiper*, *Bothiospermum*, *Rumex* sp., *Senecio vulgaris* and reported that *C. album* was the dominant weed at all wheat field having numbers ranged from 1000 to 1800 m^{-2} area (NARC, 2002). In another experimental field *P. minor*, *Alopecuros aequalis, Stellaria media, C. album, Gnaphalium affenes, Soliva anthemifolia, A. arvensis, Vicia* spp. were major weeds in wheat field during 2004/05 (NARC, 2006). About 44 species of weeds in central hills of Nepal belong to 18 families with dominance of *Chenopodium album, Polygonum plebeium* and *Spergula arvensis* were reported.

About 64 weed species of wheat from Kabhre district of Nepal (central-hill) were recorded and found 9 weed species like *P. hydropiper, A. aequalis, C. album, Polypogon fugax, P. minor, P. plebeium, A. fatua, S. anthemifolia* and *Stellaria uliginosa* as dominant in wheat (Joshi, 1996). Broadleaf weeds like *C. album, Fumaria* sp. and *Ageratum* sp. as the major weed flora in wheat field in Chitwan area of Nepal have been reported by Ranjit *et al*. (2006). Similarly, thirty weed species belonging to 16 families and 25 genera were reported in wheat field at Rampur, Chitwan, Nepal (Dangol and Chaudhary, 1993). Among them, 28 were annuals and 2 perennials. *C. dactylon, D. adscendens, A. houstonianum* and *C. album* were major weed species at IAAS, Rampur, Nepal and adjoining areas (Dangol *et al*., 1993).

In central terai of Nepal, Dangol (2001), Dangol (1987), Shah *et al*. (2011) and Dangol *et al*. (1988) reported 65, 35, 22 and 74 weed species belonging to 21, 16, 12 and 27 families, respectively. Dangol (2001) further reported *Chenopodium album, Cynodon dactylon, Polygonum plebeium, P. monspeliensis, Lathyrus* spp and *Phalaris minor* were major weeds, Dangol (1987) reported *Gnaphalium luteo-album, Chenopodium album, Cynodon dactylon, Equisetum debile, Lathyrus aphaca, Anagallis arvensis, Rumex dentatus* and *Lolium temulentum* were dominnat in Chitwan, Shah *et al*. (2011) *recorded Centella asiatica, Chenopodium album, Cynodon dactylon, Digitaria sanguinalis, Polygonum plebeium* and *Oxalis corniculata* were major, while Dangol *et al*. (1988)*reported Cynodon dactylon, Ageratum houstonianum, Gnaphalium purpureum, Chenopodium album* and *Polygonum plebejum* were major weeds of wheat in Chitwan.

A total of 68 weed species belonging to 22 families and 59 genera from the wheat field of eastern terai of Nepal (Niroula, 2013).*Anagallis arvensis*, *Grangea aderaspatana* and *Polygonum plebeium* were abundant weeds. *Chenopodium album, Cynodon dactylon, Polygonum plebeium, Lathyrus aphaca* and *Medicago denticulate* were the most common weeds in weed field of central and western terai and inner terai of Nepal (Dangol, 2001). *Gnaphalium luteo-album, Vicia sativa, Bothriospermum tenellum* and *Mazus rugosus* in central inner terai and *Plypogon monspeliensis, Rumex dentatus* and *Phalaris minor* in western terai were other major weeds of wheat field. An intensive problematic weed survey of wheat field in Chitwan district of central Nepal was conducted by Subedi (2013). In upland wheat, total of 22 species were recorded, while under lowland 37 species were found, but at lower density. Some weeds were associated to upland wheat and some were to lowland wheat. *Polypogon fudax, Polygonum plebijum, Chenopodium album, Solanum nigrum, Gnaphalium affine, Anagalis arvensis* are major weeds in wheat field on the basis of frequency of weed population and density. *Ageratum spp, Cynadon dactylon, Cyperus* spp, *Medicago denticulate, Chenopodium album* were dominated weeds in herbicide applied wheat.

A total of 71 species of weed from the wheat field of wheat in high altitude of Nepal (Manag district at altitude of 2000 m) belonging to 28 families and 66 genera were recorded by Sharma *et al*. (2010). Among them 59 species belong to di-cotyledons, 11 to monocotyledon and 1 species to pteridophyte. Out of total 71 species collected, 43 species were recorded within the wheat field and remaining 28 species were found around crop field and abandoned land.*Chenopodium album* and *Phleum alpinum* are the most dominant weed species in the wheat fields and these two also seem to be most competitive with crop plants as they grow and develop simultaneously with the wheat crop.

An intensive survey on mapping of *Phalaris minor* in wheat field of rice-wheat cropping system was conducted by Ranjit *et al*. (2006). In all districts except Chitwan, *P. minor* was reported as a problem weed but severity rankings differed in various districts. In Bhaktapur (central hill), farmers' were most concerned with grassy weeds, while in Chitwan (central inner terai), broad-leaf weeds were the major problem weeds.

3. YIELD LOSSES BY WEEDS

Rice:

The yield of 40.7% and 31.7% because of weeds in Radha-4 (weed free, 5.55 t ha^{-1} and weedy check, 4.78 t ha^{-1}) and Neemai varieties (weed free, 3.29 t ha^{-1} and weedy check, 3.27 t ha^{-1}), respectively on low land rice of far western terai of Nepal. Ranjit and Suwanketnikom (2003) reported the yield loss of weed was 25.49% in Pokhreli Masino and NR10274-10-2-1-1 cultivars having tall nature of height and higher leaf area index. Weed are estimated to caused yield losses of 17-47% in transplated rice, 14-93% in upland rice and 9-36 in wheat. Weed caused the loss of 21.54 and 23.96% under upland rice respectively in central hill and central terai even when practiced two hand weeding. During 1996, the yield losses by the weed was 27.20% under puddled transplanted condition and 6.56% yield loss even in the farmers' practices of two hand weeding.

Maize:

Under maize-finger millet relay cropping, farmers' weed management practice had reduced the 54.12 and 51.95% yield loss as compared with the weed free of maize crop on Baglung (farmers' practice, 1.683 t ha^{-1} and weed free, 3.668 t ha^{-1}) and Parbat district (farmers' practice, 1.628 t ha^{-1} and weed free, 3.388 t ha^{-1}) on western mid hills of Nepal (Karki *et al.,* 2014). Maize is most sensitive to weed competition during its early growth period of 2-6 weeks after sowing due to profuse weed germination and rapid growth of weeds resulted by wider row spacing of maize. At ARS Pakhribas (eastern mid hill of Nepal) experimental result showed weedy environment resulted yield reduction up to 70% in maize (Mishra, 2004). Shrivastav (2014) observed the yield loss by 37.32 during the spring season in central terai of Nepal.

Wheat:

Weeds were estimated to cause yield losses of 9-36% in wheat(Ranjit et al., 1998). *Ploygonum hydropipper* reduced wheat yield by 50% (Harrington *et al.*, 1992). The weed had reduced the grain yield of wheat by 11.73% under rice-wheat system under sub-humid condition of inner terai of Nepal (Shivakoti *et al.*, 1977).

4. WEED MANAGEMENT PRACTICES

Rice:

- The increasing wage rate and labour scarcity forced the farmers' to adopt the integrating herbicides in the weed management practice. Pre-emergence application of Pendimethalin @ 1 kg a. i. ha^{-1} fb by post emergence application of 2,4-D sodium salt @ 0.5 kg a.i. ha^{-1} fb hand weeding under normal seed bed and Pendimethalin fb Bispyribac Na @ 25 g a. i. ha^{-1} at 20 days of seeding under stale seed bed for dry-DSR resulted best alternative for manual hand weeding practices (Bhurer *et al*., 2014).
- Both in central hill and terai, the pre-emergence application of Pendimethalin @ 2 kg a.i. ha^{-1} showed the good effect in controlling the weeds in upland rice and yielded the highest yield (central hill, 4257 kg ha^{-1} and 3540 kg ha^{-1}central terai) which was significantly better than two hand weeding, pre-emergence application of Butachlor @ 2 kg a.i. ha^{-1}, Butralin @ 2 kg a.i. ha^{-1}, Oxyflurfen@ 1 kg a.i. ha^{-1}, Thiobencarb @ 3 kg a.i. ha^{-1} and Propanil @ 2 kg a.i. ha^{-1}.
- Butachlor 2 kg a i ha^{-1} and Butachlor 1 kg a i ha^{-1} fb hand weeding was equally effective in weed control on puddled transplanted rice in central hill during 1997 having little yield benefit (6.56%) over farmers' practice of two hand weeding. While in following year, Butachlor 1 kg a i ha^{-1} fb hand weeding was best in terms of weed dynamics and yield (7338 kg ha^{-1}) which was more effective than 2 hand weeding (6296 kg ha^{-1}) and Butachlor 2 kg a i ha^{-1} (5255 kg ha^{-1}).
- Under both Chinese seed drill planted rice and pudlled transplanted rice, post emergence application of Butachlor 2 kg a i ha^{-1} was superior than the 2 hand weeding in central hills of Nepal.
- The use of Pendimethalin fb 2, 4-D fb one hand weeding produced yield (5161 in 2010 and 6160 kg ha^{-1} in 2011) which were statistically at par with yield (5305 in 2010 and 6319 kg ha^{-1} in 2011) obtained under the weed free treatment.
- Compared to weed-free plots, the grain yield was 1.5% lower in twice hand-weeded plots (25 and 50 DAT) and 4.0% in Butachlor treated plots (1.5 kg a.i. ha^{-1}). The effect of manual weeding and Butachlor application significantly at par.
- Ranjit and Suwanketnikom (2003) concluded that mulching of straw at 4 t ha^{-1} was also a better alternative (only 16.67% lower yield) of 2 hand weeding was superior (4.80 t ha^{-1}).
- During 1987/88, application of pre-emergence herbicide Butachlor at 1-2 kg a.i. ha^{-1}, pre plant incorporation herbicide Fluchloralin at 0.75-1.5 kg a.i. ha^{-1} were equally effective to 3 hand weeding at 21, 42 and 63 DAT and superior than post emergence 2, 4-D application at 1-

2 kg ha^{-1} and pre-emergence application of Benthiocarb at 2-4 kg a.i. ha^{-1} under loamy soil of central Nepal at Rampur, Chitwan under conventional transplanted rice.

- Application of Bispyribac at 80 ml ha^{-1} as post emergence application fb one had weeding (3.43 t ha^{-1}) was equally effective to the three hand weeding in dry-DSR (3.17 t ha^{-1}) under inner terai of Nepal (Gaire *et al*., 2013).
- Among two mulch (wheat straw 5 t ha^{-1} and *Eupatorium* 5 t ha^{-1}) and three brown manuring treatments (*Sesbania* 30 kg ha^{-1}, Sesamum 2 kg ha^{-1} and *Crotolaria* 30 kg ha^{-1}), mulching with E*upatorium* had the highest grain yield of dry-DSR (3.50 t ha^{-1}) which was significantly higher than wheat straw mulch (2.83 t ha^{-1}) and Sesamum brown manuring (2.97 t ha^{-1}) but statistically similar with the brown manuring of *Sesbania* (3.17 t ha^{-1}) and *Crotolaria* (3.23 t ha^{-1}) which are comparable with three hand weeding (Gaire *et al*., 2013).
- The *sesbania* co-culture (50 kg seeds and killing at 4^{th} weeks after seedling) had produced significantly higher grain yield than sole Bispyribac Na application.
- Weed free, Pendimethalin fb Bispyribac Na application, Pendimethalin - 2, 4-D application and *Sesbania* with 50 kg seeds and killing at 4^{th} weeks after seedling had statistically similar.
- Two hand weeding at 28 and 40 DAS as farmers' practice had only 4.79% yield advantage over *Sesbania* with 50 kg seeds and killing at 4^{th} weeks after seedling under *Sesbania* rice co-culture. The optimum seed rates and killing dates of *Sesbania* under *Sesbania* rice co-culture were obtained as 31.67 days (nearly 32 days) and 102.28 kg ha^{-1} (nearly 102 kg ha^{-1}), respectively.
- During the monsoon rice, the effectiveness of stale seed bed was not much greater (0.37%) than the normal seed bed.
- The herbicide Anilophos, Pretilachor and Pendimethaline are more effective than Fenoxaprop. Anilophos fb one hand weeding produced highest grain yield (4350 kg ha^{-1} that is 613 kg more than hand weeding), and Pretilachlor fb one hand weeding (4263 kg ha^{-1} and 520 kg more than hand weeding treatment) were the best weed management practices in the transplanted rice field.
- During both years of experiments, The best weed management practice for dry-DSR was pre-emergence Pendimethalin (1 kg a.i. ha^{-1}) fb Bispyribac Na (25 g a.i. ha^{-1}) which had comparable yield with weed free in central inner terai of Nepal.

Maize:

- Repeated application of both herbicides Glyphosate 2.0 l ha^{-1} and 2,4 -D 2.0 kg ha^{-1} 1 at 17 and 37 DAS reduced the violet wood sorrel (*Oxalis corymbosa*) weed population in maize field and for its eradication more repeated application of herbicides has been required (KC, 2007).
- Dahal *et al*. (2014) reported the application of Atrazine as pre-emergence herbicide was equally effective to the 3 manual weeding on residue removal treatments while significantly better under previous crop residue retention on maize crop of rice-wheat rotation under central inner terai.
- The highest grain yield was recorded in the plot where Pendimethalin was applied as pre-emergence and Na Bispyribac as post-emergence herbicide followed by the plot where Pendimethalin as pre-emergence herbicide was applied indicating that combination of Pendithemalin and Bispyribac was also effective even in summer maize.

- Co-culture of buckwheat followed by one hand weeding was equally effective as hand weeding at 45 DAS and earthing up in the summer maize production in central terai region of Nepal.
- Pre-emergence application of Pendimethlin @ 1 kg a. i. ha-1 was far better (110.93% higher yield) than the Atrazine @ 1 kg a. i. h^{a-1} in summer maize.
- The grain yield obtained with tank mixture of Atrazine (0.75 kg a. i. ha^{-1}) and Glyphosate (1.0 l a. i. ha^{-1}), was comparable with Pendimethalin (1.0 l a. i. ha^{-1}) fb one hand weeding at 40DAS and these treatments are superior over its sole application. The highest net returns were obtained in tank mixture of Atrazine and Glyphosate.
- Sole application of Atrazine (1.5 kg a. i. ha^{-1}) as pre-emergence was slightly better (3.01% higher yield) than two hand weeding at 30 and 65DAS in maize-mustard system of western hills of Nepal (Karki, 2014).
- In an experiment under rice-maize system in central inner terai, the yield of winter maize under manual weeding (45 and 80 DAS) was 5.97 t ha^{-1} as compared to 6.07 t ha^{-1} in herbicide (1.5 kg a. i. ha^{-1}) applied plot (Karki, 2014).

Wheat:

- In central hill, the highest grain yield (3374 kg ha^{-1}) obtained with the application of pre-emergence application of Isoproturan @1.0 kg a i/ha + HW at 30 DAS (2593 kg ha^{-1}) which was equally effective as post emergence application of Dicuran @ 1.0 kg a I ha^{-1}. While at western terai, pre-emergence application of Isoproturan @2 kg ai/ha which was equally effective as post emergence application of Harmony @ 25g ha^{-1}, pre-emergence application of Isoproturan @1.0 kg a I ha^{-1} + HW at 30 DAS and Dicuran 1-2 kg a i ha^{-1}.
- Weed dry weight and numbers were less in RT followed by CT and ZT resulted in the highest yield under RT (2835 kg ha^{-1}) which is comparable to CT (2550 kg ha^{-1}) and the lowest yield was obtained in ZT (1204 kg ha^{-1}).
- Pre-emergence application of Isoproturan fb post emergence application of 2, 4-D was most effective weed control measures even in ZT.
- The result reported by Sthapit (1986) indicated that the post emergence application of selective herbicide, Isoproturon 50% WP with 3.0 g l^{-1} of water at 30 DAS of wheat sowing significantly increased the wheat yield by 57.5% over the un weeded checked plots.
- Weed control efficiency of Leader @ 30 g a.i. ha^{-1} was higher than hand weeding and application of Fenoxaprop @ 1.0 l ha^{-1} and Metribuzin in central hill of Nepal. But the grain yield was the highest in hand weeded plots and it was statistically similar with the Leader @ 28 and 30 g a.i. ha^{-1} and Fenoxaprop @ 1.0 l ha^{-1}.
- Though the highest yield was obtained in one hand weeded plot (2067 kg ha^{-1}), Sulfosulfuron @ 28 g a.i. ha^{-1} (1641 kg ha^{-1} was most economical in weed control of wheat in central hills of Nepal.
- Sulfosulfuron @ 28 g a.i. ha^{-1} application was much better than the other recent used herbicides (Sencor 500 g a.i. ha^{-1}, Isoproturan fb 2, 4-D, Isoproturan and Fenoxaprop1.0 l ha^{-1}) for controlling the weeds and increasing yield of wheat.
- Post-emergence application of Isoproturon @ 2 kg a.i. ha^{-1}, Dicuran 2 kg a.i. ha^{-1}, Isogourd 1-2 kg a.i. ha^{-1} and reemergence application of Isogourd 2 kg a.i. ha^{-1} and Isoproturon @ 2 kg a.i. ha^{-1} were equally effective in terms of weed dynamics and yield. These all herbicides were much better than the post emergence application of 2, 4-D Na salt @ 1 kg a.i. ha^{-1}.

- Rice straw mulching @4.0 t ha^{-1} was more advantageous for controlling weeds and yielded 21.41% than the hand weeding at 30DAS.
- The highest grain yields were 4104 and 3878 kg ha^{-1} recorded in Sulfosulfuron with and without mulch, respectively, followed by hand weeding (3770 and 3478 kg ha^{-1}) with and without mulch. The lowest grain yield 2819 and 1684 kg ha^{-1}, was recorded in the weedy check with and without mulch respectively. In all treatments, grain yields were higher with mulch compared to without mulch (Ranjit *et al.*, 2006).
- Traditional practice of one hand weeding, post emergence application of Sulfosulfuron @ 28 g a.i.ha^{-1} and Sulfosulfuron 26 g a.i. ha^{-1} with straw mulch (4.0 t ha^{-1} rice straw) gave higher yield (2914 kg ha^{-1}, 2906 kg ha^{-1}, and 2647 kg ha^{-1}, respectively) than post emergence application of Fenoxaprop-P-ethyl @100 g a.i. ha^{-1} (2194 kg ha^{-1}) (Ranjit and Suwanketnikom, 2003).

5. TOXICITY OF HERBICIDES

Thapa (2012) observed the slight toxic effect of herbicides on paddy plants at 21 days after transplanting of paddy seedlings. However, it did not persist for long and had no overall harmful effect on grain yield (Table 1).

Table 1. Toxicity rating of herbicide (mean ± SD) on paddy var. Radha 7 and Khumal 5

Treatments	Rate of application (kg ha^{-1})	Radha 7				Khumal 5			
		Toxicity rating scale of 0-100 DAT							
		21	42	63	84	21	42	63	84
Butachlor	1.5	14.0±1.7a	5.0±0.9a	2.0±0.1a	0.0a	16.0±1.9a	6.0±1.0a	3.0±0.3a	0.0a
2,4-D	1.0	17.0±1.9b	6.0±1.0b	3.0±0.2b	0.0a	19.0±2.1b	8.0±1.7b	3.0±0.4a	0.0a

Mean ±SD in each column followed by the same letter do not differ significantly at P = 0.05 by Duncan's Multiple Range Test (DMRT) followed after ANOVA

CONCLUSION

Wide range of agro-climates, soil types and diverse farming systems results in complex weed dynamics. The variable weed incidence is crops and contexts specific that determined the yield loss, and observed up to 70% besides deteriorating the quality and causing health and environmental hazards. Due to higher price of scare labor, herbicidal weed control is felt as the next options. Herbicides applied alone or in combinations, have been regarded as essential tools for effective management of weeds in different agro-ecosystems.

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REBUILDING LOCAL SEED SYSTEM AND SAFEGUARDING CONSERVATION OF AGROBIODIVERSITY IN THE AFTERMATH OF NEPAL 2015 EARTHQUAKE

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ABSTRACT

A study was conducted from July 2015 to December 2017 to rebuild local seed system and safeguard conservation of agrobiodiversity in the aftermath of earthquake through rescue collection, conservation and repatriation of endangered crop landraces from 10 earthquake affected districts. The process employed several methods, approaches and processes combining rescue missions with qualitative and quantitative assessments techniques and tools. The process helped to assess status of diversity of traditional crops, identify endangered, extinct and rare crop landraces, document and characterize their unique agronomic traits and develop and validate methodology for conservation of native crops by linking on-farm and ex-situ approaches. A total of 921 accessions of 61 crops were collected from 35 VDCs of 10 severally earthquake affected districts. The process has identified 104 lost crop landraces and rescued 284 rare and endangered ones and conserved them in national Genebank. Some of the farmer demanded crop landraces are repatriated back to local communities and also conserved in community seed banks in affected districts.The process therefore helped to restore lost diversity, revive and strengthen the local seed system and safeguard biodiversity of native crops to adapt to more extreme and changing climatic conditions.

Keywords: Adapted seeds, capacity building, conservation, rebuilding, repatriation, rescue collection

INTRODUCTION

The April 25 earthquake (with 7.6 Richter scale) and its subsequent aftershocks have had significant impact on people's livelihoods, agriculture and agrobiodiversity in Nepal. The major effect of disaster was in remote hills and mountains where production system was rainfed, risk-prone, subsistence and people's livelihoods depended on agriculture and biodiversity of traditional crops. According to the estimates of the Post Disaster Need Assessment (PDNA) of the Government of Nepal, the total value of direct and indirect impact of the earthquake to Nepalese economy was close to USD 7 billion, equivalent to one-third of country's GDP (NPC, 2015).The agriculture sector suffered total damage and loss of USD 255 million, with maximum losses (86%) in mountainous and hilly - affected areas (Rasul etal., 2015). The country's vulnerable areas had been most affected, leaving over 3.5 million people in need of food, water, shelter and medical assistance (FAO, 2015). Over 70% of the agricultural households have lost their more than 60% of their seed stock and crop genetic resources stored in their household stores from earthquake damage (FAO, 2015; NPC, 2015). The earthquake had also secondary effects, triggering human and nature induced landslides, land degradation, flooding, drying up of water sources, avalanches and disease epidemics. It also had

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long-term negative impact on agricultural and national development through the loss of productive laborforce, infrastructure, forced outmigration and disruption in supply chains and earning potentials of people (NPC, 2015). The disaster had significant effect on the agriculture and agrobiodiversity due to destruction of storage structures, burial of stored seeds and damage of agricultural lands (Gauchan et al., 2017).

Seed is at the heart of restoring food security for farmers and their familiesin Nepal. Farmers in rural and remote hills and mountains have high dependence on food security by producing agricultural production from self-saved and locally exchanged seeds and biodiversity of traditional crops. Estimates show that over 90% of the farm households in rural hills and mountainous regions of earthquake affected regions of Nepal depend on self-saved and locally exchanged seeds of traditional crops in the communities (Gauchan et al., 2016). The majority of the affected families were smallholder farmers, with low capacity to respond and recover from shocks. Therefore, rescue collection of native and endangered seeds was important after disasters in order to revive local seed system, restore lost diversity and safeguard local crop biodiversity for future generation (Bioversity International, 2016; Gauchan et al; 2016).

Aftermath of the disaster, various national government and international relief agencies made efforts in Nepal to rescue human beings, livestock and valuable assets but no immediate initiatives were made to rescue endangered native crop seeds and varieties in the affected areas in Nepal (Gauchan et al 2016). Considering the critical role of local and native varieties in rebuilding local seed system, improving livelihoods of mountain communities and safeguarding biodiversity of globally important crops, Bioversity International jointly in partnership with National Genebank, NARC and LI-BIRD initiated a study from July 2015 to December 2017 on rescue seed collection, conservation and repatriation of local crop genetic resources that are endangered from earthquake areas. This paper deals with the role, process, methodologies and achievement made in rebuilding local seed system through rescue collection, conservation and repatriation in 10 earthquake affected areas.

OBJECTIVES

The main objectives of the study were to (i) rebuild local seed system of native crop varieties in earthquake affected areas through rescue collection, conservation and repatriation and (ii) develop and validate methodology of rescue collection for seed recovery, livelihood improvement and safeguarding biodiversity of native crops.

METHODOLOGY

The study employed several methods and approaches combining both qualitative and quantitative methods for rescue collection, conservation and repatriation of native crops seeds in affected areas. The process of rescue collections was initiated in 35 village development committees (VDC) of 10 severely affected districts covering 2-4 most severely affected VDCs of each district (Figure 1). Participatory rural appraisals focusing on key informant interviews, transect walks and focus group discussion (FGD) were carried out for identification of appropriate locations and communities for rescue collection, conservation and repatriation. FGD and 4-cell analysis were carried out in selected communities to identify rare native crops and landraces that need rescue collection, conservation and repatriation in local communities. Passport data filling with sample seed collection and survey of 837 farmers were carried out where seeds are collected and rescued for the documentation of rescued seed types, crop varieties and farmers' knowledge that are being collected and rescued.

After rescue mission and field survey, assessment was carried out to characterize and document diversity of traits of traditional crops, identify endangered, extinct and rare crop landraces and develop and validate methodology for conservation of native crops by linking on-farm and ex-situ approaches. Data were also captured by employing DIVA GIS software and CAT (Climate Analogue Tool) using rice germplasm from national and international genebanks. DIVA-GIS software was used to construct a collection map and use Climate Analogue Tool (CAT) to identify the analogue sites of earthquake affected areas. Seed samples that donot meet standard gene bank requirements and those demanded by farmers were planted in the genebank fields for seed increase, characterization and evaluation. Some of the farmer preferred landraces seeds of 4 crops (rice, foxtail millet, lentil and naked barley) were re-introduced and repatriated back to local communities in affected districts of Dolakha, Kavre and east Lamjung for building local seed system, providing local access of seeds and conservation in community seedbanks and farmers fields. Monitoring and follow-up for feedback collections were carried out in repatriated locations and communities for their suitability and adaptability. Rescue collected seed sample data and information including methodology and findings were supplemented and validated through review of available national and international literature, field characterization and evaluation and consultation meetings and workshops with relevant stakeholders at the local and national level.

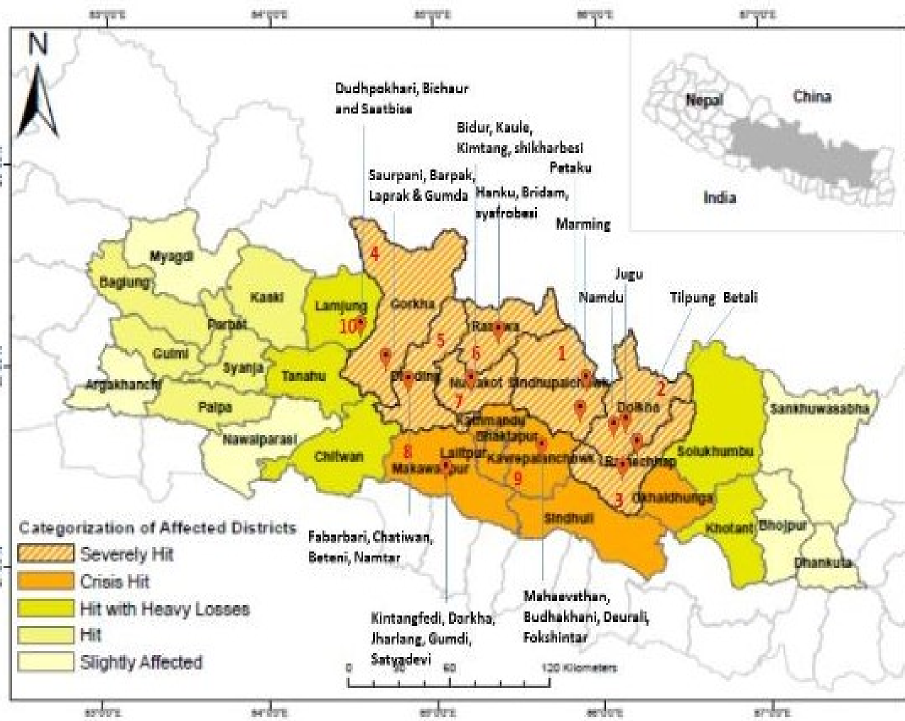

Figure 1. Rescue collection of crop landraces from earthquake districts: Map source: NPC (2015)

RESULTS AND DISCUSSION

RESCUE COLLECTIONS, CONSERVATION AND PARTICIPATORY SEED EXCHANGE

A total of 921 accessions of 61 crops were collected from 35 VDCs of 10 severally earthquake affected districts. The germplasm rescue project implemented by the National Genebank (NAGRC) with the funding support of Global Crop Diversity Trust (GCDT) collected 513 crop landraces of 57 crops while Seed Rescue Project implemented by LI-BIRD with the funding of Genetic Resource Policy Initiative -Phase 2 (GRPI-2) project of Bioversity International collected 410 accessions of 46 crops. Out of those collected samples, the large proportion of the crop landraces collected and rescued were cereals (37%) followed by legumes (33%) and small proportion of pseudo cereals, oilseeds, vegetables and spices (Figure 2).

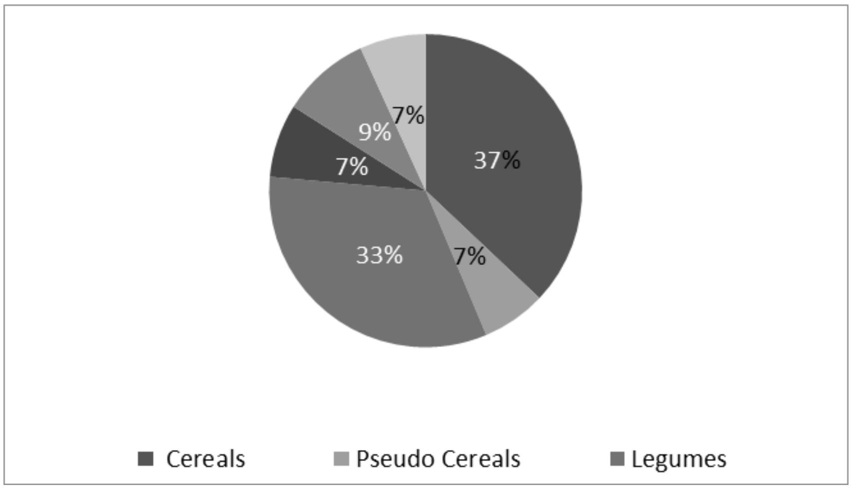

Figure 2. Proportion of sample collected by crop groups in earthquake affected areas

These collected samples were processed (cleaning, germination testing, drying) for conservation in Genebank for future use in affected areas as well as for future crop improvement. Seed samples that did not meet standards and quality for safe storage in genebank are planted in the fields for their seed increase, regeneration and phenotypic evaluation. Part of the rescue collected endangered seeds of cereals, legumes and vegetables (20 landraces in Dolakha and 18 landraces in Lamjung) were also conserved in local community seed banks of earthquake affected areas such as in Jungu Dolakha and Rainash in east Lamjung. The rescue collected rare and endangered seeds from three earthquake affected districts of Dolakha, Ramechhap and Sindhuplanchowk were distributed back immediately to local communities by employing participatory seed exchange (PSE) method. The objectives were to provide immediate access of locally adapted seeds to disaster affected communities for their immediate food production and also the revival of their damaged local seed system. A total of 503 farm households received rescued rare and endangered seeds and participated in PSE (Gautam et al., 2017) whichsignifies importance of seed exchange to the affected communities for revival of the local seed system and ensuring local food security. Smallholder farmers and women were the key beneficiaries of the PSE.

ASSESSMENT OF CROP DIVERSITY

The rescue collected crop landraces were assessed, characterized and documented based on passport data information, visual seed observation and on-farm evaluation of selected ones. The process helped to identify crop landraces that are endangered, extinct, rare and abundance in surveyed 10 earthquake affected districts. The assessment revealed that a total of 104 crop landraces are lost, 26 of rare and unique and 258 seed types of different crops are at endangered state due to earthquake and other factors (Figure 3).

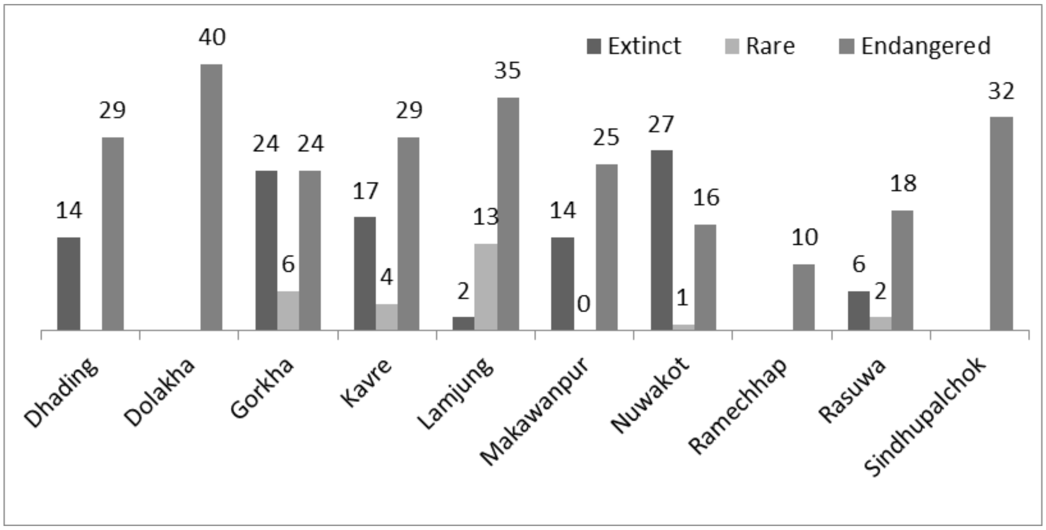

Figure 3. Status of endangered, rare and extinct crop landraces in earthquake affected areas

Endangered native landraces in affected areas were observed for various food crops in most parts of mid hills and high hills/mountains of the affected areas due to direct and indirect consequences of earthquake and other subsequent effects of disaster. Furthermore, we carried out supplementary survey of 131 households in 17 VDCs of severely affected four districts of Gorkha, Nuwakot, Kavre and Rasuwa to assess farm level richness and evenness of dominant rescue collected crops. The findings showed the declining community and farm level richness and evenness of crop biodiversity of rice, maize and finger millet in most of the surveyed households. The major perceived causes of genetic erosion occurring in the surveyed areas and germplasm at risk are the *ad hoc* distribution of large amounts of improved, untested seeds as relief materials from external agencies, the sudden migration of farmers after the disaster and attraction of rural farm households towards other alternative income generating options (Gauchan et al., 2016; Sapkota et al., 2017).

DEVELOPING AND VALIDATING METHODOLOGY

The study has played important role in developing, testing and validating available methods for post-disaster revival of seed system and safeguarding biodiversity of traditional underutilized crops. The study has developed methods for analogue sites identification (Poudyal et al., 2017); and red listing of crop genetic resources similar to forest and broader plant and animal biodiversity (Joshi et al., 2017) and helped in identifying gaps in collections in Genebank and methods for repatriation methods (Dongol et al., 2017). Mapping of the existing genebank collection was carried out to identify gaps in collections in earthquake affected districts to initiate the rescue collection in those locations where previous collections are missing and endangered crop seeds need to be rescued (Ghimire et al., 2017). The process has helped in validating 4-cell analysis to identify endangered and rare crop genetic resources for rescue collection and conservation in Genebanks (Sapkota et al., 2017). The work also supported validation of methodology for participatory seed exchange (PSE) for rescue collection and revival of local seed system after disaster (Sthapit and Gautam, 2016; Gauchan et al., 2016) and testing and validation of climate analogue tools (CAT) for the suitability of rescue collected germplasm for repatriation in similar affected areas (Poudyal et al., 2017).

DOCUMENTATION AND CHARACTERIZING VALUABLE AND UNIQUE LANDRACES

Documentation and characterization of rescued collected samples are essential for their protection, immediate use in cultivation and future use in crop improvement. The collected seeds were assessed to the processing (germination, drying) and regeneration through data captured. The collected samples which did not meet adequate Genebank standards (e.g. adequate quantity, germination percent) were used for seed increase and further processing. Some of them are in the cleaning and drying process in Genebank for long-term safe storage. Most of the collected samples were further evaluated, characterized and regenerated for their evaluation, multiplication and documentation of unique and rare traits. A total of 173 samples (accessions) of 11 crops were characterized in the fields for their agronomic traits. The study has supported national genebank of Nepal for characterization and documentation of unique and rare germplasms and traits from earthquake affected districts for future us in crop improvement.

STRENGTHENING LINKAGE BETWEEN ON-FARM AND EX-SITU APPROACHES

The process has rescued 284 rare and endangered crop landraces (26 rare and 258 endangered) from on-farm (farm households and fields). They are processed and conserved in both National Genebank and partly in Community Seed banks located in earthquake affected areas of east Lamjung (Rainash) and Dolakha (Jungu village). Farmer' preferred ones are multiplied and shared with disaster affected local communities through diversity kits distribution and organizing participatory seed exchange (PSE) with local communities. Over 90% of the collected and shared seeds in the earthquakeaffectedlocalcommunitieswerenotintheofficialnationalnotified list of crop varieties (Sthapit and Gautam, 2016) and of the lists of national genebank collections (Gauchan et al., 2016). The process has helped linking national Genebank with community seed banks and farming communities in risk prone mountains areas for holistic conservation. During the rescue collection and study process, training and orientation were provided to farmers and members of Community Seed Bank in east Lamjung for safe storage, conservation and methods of cultivation for their use.

LINKAGES AND SYNERGIES WITH ON-GOING INITIATIVES

The study made significant efforts to link with on-going initiatives and develop synergies with on-going programmes and project of NARC, LI-BIRD and Bioversity International in Nepal for rebuilding local seed system in the aftermath of disaster. The rescue collection work carried out in the first phase in three districts (Ramechhap, Dolakha and Sindhuplanchowk) was linked with LI-BIRD's Rebuilding Family Farm (RFF) programme (Sthapit and Gautam, 2015).The study was also linked with an existing Global Environment Facility (GEF) and United National Environment Programme (UNEP) funded local crop project in the affected districts (Dolakha and Lamjung), which is being implemented jointly by Bioversity International, NARC, LI-BIRD and Department of Agriculture (DoA) in Nepal. GEF UNEP Nepal project has organized a Diversity (Seed) Fair in Jugu VDC (now Gaurishankar Rural Municipality) of Dolakha district on 2 April 2016 as part of on-going project activities, in which this activity was linked to generate supplemental information and validate the type of rescue collected materials. The work has also supported to on-going activities in other GEF project sites such as Lamjung, Jumla and Humla districts through on-farm testing of rescue collected seeds and also linked to Bioversity implemented "Smallholders seed security for food security project" funded by Swiss Agency for Development Cooperation (SDC) and implemented by NARC and LI-BIRD. The work has also been linked with on-going programmes and projects of the National Genebank and those of NARC Research Programmes and Stations for collection, conservation and use of native crop landraces in crop breeding and research programme. In addition, the rescue collection was linked with the local NGO, COPPADES (Community for the Promotion of Public Awareness & Development Studies) that had initiated relief work and community seed bank activities in Rainash, eastern Lamjung, linking with its activities in earthquake affected areas. Collaboration with local stakeholders and district agricultural offices (DADOs) also provided visibility and applicability of work to rescue endangered seeds and develop plan for repatriation to real target group of farmers.

SENSITIZING STAKEHOLDERS ON RESCUE COLLECTION, CONSERVATION AND REPATRIATION

Sensitization of local stakeholders and communities was key component of the process of rescue collection. This was carried out both for seeking local support in rescue collection and creating awareness for conservation of rare and endangered traditional crop seeds and safeguarding genetic diversity for food security. In addition, two major district level interaction workshops were carried out during the study process. The study made significant efforts to organise district level interaction and awareness programme on Rescue Collection in Charikot, Dolakha in 22 Feb 2016 and in Dhunche, Rasuwa on 7 Dec 2016 by involving local district government offices, relevant district stakeholders and communities. The events were special not only sensitizing local stakeholders for rescue collection and conservation but also provided venue for official handover of rescue collected seeds particularly in Charikot (Dolakha) for conservation in National Genebank of Nepal. There was a very good response from district level stakeholders and local communities on the role of rescue collection, repatriation and conservation of native seeds for future generation. The work on revival of local seed system after disaster was also communicated widely to relevant stakeholders through organizing national sharing workshop and participating in international workhops(eg International Agrobiodiversity Workshop New Delhi, 6-9 November 2016 and International Mountain in Changing World Conference, Kathmandu 2-3 October 2016) in addition to sharing through news media (FM Radio, TV), social media (facebook), research papers and news blogs in the Bioversity International and GEF UNEP Prokject websites (eg www.bioversityinternational.org; www.himalayancrops.org).

STRENGTHENING LOCAL AND NATIONAL CAPACITY ON RESCUE COLLECTION & CONSERVATION

The work has helped in building national capacity for rebuilding local seed system after disaster through rescue collection, conservation, seed multiplication and repatriation and laying a foundation for community seed bank in Jungu Dolakha. The study was linked in building the capacity of researchers, local field staff and interns for collection missions with GEF UNEP project of NARC, DoA and LI-BIRD and "Rebuilding Family Farm (RFF)" project of the LI-BIRD. During the process, the capacity of researchers of NARC National Genebank, DADO and LI-BIRD that were engaged in GEF UNEP and RFF projects respectively were enhanced. In addition, it also provided opportunity for building capacity of two young graduate students (interns) in carrying out research, where one of them accomplished MS thesis on the topic related to rescue collection and conservation of native crop seeds. The study also collaborated with COPPADES in eastern Lamjung to train local staff and farmers involved in community seed banks for rescue collection and safe conservation in community seed banks and use of collected seeds for ensuring local food security.The collaboration with the District Agriculture Development Offices (DADOs) and key informant farmers in earthquake affected districts provided opportunity to sensitize and enhance capacity of district agricultural staff and local knowledgeable farmers of the affected districts in rescue collection and conservation. The work of rescue collection supported by GRPI-2 project of Bioversity International provided seed money of US $ 8,000 to earthquake affected Jungu Community in Dolakha district for laying foundation of Community Seed Bank establishment (Sthapit and Gautam 2016), which is being further supported and strengthened through on-going activities of GEF UNEP project.

CONCLUSIONS AND WAYS FORWARD

Rescue collection, conservation and repatriation of native and endangered seeds are important after disasters in order to restore lost diversity, revive local seed system and safeguard local crop biodiversity for future generation. During rescue collection, a large proportion of native crop varieties were found in endangered state and some had already extinct in the study areas. The loss of diversity was not only from the impact of earthquake damage but also from the emergency relief of*ad hoc* distribution of large amounts of improved, hybrids and untested seeds as relief material from external agencies, the sudden migration of farmers after the disaster and attraction of rural farm households towards other alternative income generating options. The main outcome of the study was to rebuild local seed system and promote conservation through rescue seed collection missions, seed multiplication and repatriation in severely earthquake affected villages. It was possible to rescue 284 rare and endangered crop landraces and conserved in Genebank, out of which some of the rare, endangered and farmer demanded ones are repatriated back to local communities for reviving local seed system.The study has helped to assess status of diversity of traditional crops, identify endangered, extinct and rare crop landraces, document and characterize their unique agronomic traits and develop and validate methodology for conservation and rebuilding local seed system of native crops in disaster-prone areas. The process has helped to store part of the collected seed samples in community seed banks for local access, availability and use. This strategy was useful to promote both ex-situ and on-farm agrobiodiversity conservation, rebuild local seed system affected by disaster and help to safeguard native crop biodiversity for future generationto adapt to more extreme and changing climatic conditions. The process has also helped building national capacity and resilience to cope with future disasters and laying a foundation for community seed banks by linking national gene banks with community seed banks and farming communities in risk-prone mountain areas.

Future priority in relief and rebuilding agriculture therefore should be given to rescue collection, conservation and repatriation in disaster prone areas. Focus should be on access and availability of locally adapted varieties and quality seeds of the local crops, that perform well in farmers' existing management systems and changing climate conditions, since locally adapted seeds are the heart of agriculture and food security of vulnerable people in fragile affected areas. Regular monitoring, collection and repatriation program will be more effective to conserve the underutilized and other crop landraces diversity in marginal areas.Promotion of traditional crops and their adapted seeds enhance not only sustainability of local agricultural system but also promote conservation and safeguard biodiversity of traditional crops. Finally, there is a need to rebuild human resource, institutional capacity and governance in agrobiodiversity conservation and building local seed system linked to disaster risk reduction through massive training and capacity building of youth in agriculture and agrobiodiversity conservation.

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EFFECTS OF *Acorus calamus* (L.) RHIZOME POWDER ON MAIZE WEEVIL (*Sitophilus zeamais* Motschulsky) UNDER LABORATORY CONDITION

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ABSTRACT

Maize weevil (Sitophilus zeamais Motschulsky) is a serious pest of maize in storage. The use of pesticide is a common practice to protect maize grains which is hazardous to human health and environment .An experiment was conducted from June to November, 2016 in the laboratory at National Maize Research Program, Chitwan. For its management, different concentration of Acorus calamus (L.) rhizome powder (@2.5, 5, 10, 15 and 20g and Malathion @ 2g per kg maize grains were evaluated. Five pairs of adult male and female weevils were mixed in separate muslin bags in completely randomized design with three replications. This study showed that A. calamus rhizome powder @15gm was the best that resulted in less grain damage and the higher germination of treated maize grains. Therefore, A. calamus rhizome powder can be used for management of S. zeamais in post-harvest storage of maize.

Key words: *Acorus calamus,* maize storage, maize weevil

INTRODUCTION

Maize (*Zea mays* L.) is the second most important cereal crop after rice in Nepal and it is commonly grown during summer season. The total area, production and productivity of maize was 928761ha, 228322 mt and 2.458 mt/ha respectively (MoAD, 2014). It contributes about 25.02% in total cereal production, 3.15% to National GDP and 6.54% in AGDP (MoAD, 2013). According to Ranum et al. (2014) per capita maize consumption in Nepal is 98 g/person/day. The major maizeproducing regions in Nepal are mid hill (72.85%), terai (17.36%) and high hill (9.79%), respectively. Annual growing demand of maize production is increasing constantly at the rate of 5% and maize area and production has shown a steady increase, but productivity has been low (2.46 mt/ha) in comparison to other countries (Sapkota & Pokhrel, 2010).

Post-harvest losses of agricultural commodities have been considered as a major problem in developing countries like Nepal. Upadhyay (2000) reported that storage loss of maize was 8%, 7.4% and 13% in mountains, hills and terai respectively. Maize weevil (*Sitophilus zeamais* Motschulsky) is dominant species on maize, which causes 5-30% of the total grain weight of the stored product (Ojo and Omoloye, 2012). The use of chemical pesticide in storage and consumption of treated grains is hazardous to health in comparison to botanical pesticides. Othira, Onek, Deng and Omolo (2009) reported that Acorus calamus powder have insecticidal activity against maize weevil (Sitophilus zeamais). Similarly, Schmidt & streloke, 1994; Yao Cai Yang Xue & Huang (2008) reported a research result demonstrated that ß-asarone as the main bioactive insecticidal compound of acorus calamus. In the same way Entomology division of Nepal Agricultural Research Council Khumaltar (1996)

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reported that different concentrations (2, 1 and 0.5g per 100g of grains of sweet flag gave 100% mortality within one week and 50% mortality within 3 days.Therefore, this study was conducted to evaluate the different concentration of *Acorus calamus* (L.).

MATERIALS AND METHODS

An experiment was conducted in a completely randomized design (CRD) with 3 replications and 7 treatments A. *calamus* rhizome powder @ 2.5, 5, 10, 15, 20g/kg malathion 5 % DP @2g/kg maize grains and a control (without any treatment) in Entomology Laboratory, NMRP, Rampur, Chitwan. Muslin cloth bags size 30x40 cm type of containers were used for Mankamna-1 variety of maize grains.Reared male and female weevils were separated based on length and breadth of snout and ridge with the help of binocular microscope holding weevil in suction pipe. Then five pairs of adult maize weevils were released in each treatment. Climatically, the location falls under sub-tropical inner Terai (Siwalik dun valley) region with an average annual temperature and rainfall 2,033 mm, respectively.

This study was carried out from June to November, 2016. Data were recorded on grain damage percent using formula (Adams and Schulten (1978) and Duna (2003)

$$\text{Percent damage grains} = \frac{\text{No. of bored grains}}{\text{Total number of grains in sample}} \times 100$$

GRAIN WEIGHT LOSS

Undamaged and damaged grains were counted and weighted separately and percent weight loss was calculated as follows (Prakash et al; 1987)

$$\text{Percent weight loss} = \frac{UNd - DNu}{N(Nd + Nu)} \times 100$$

Grain moisture testing : The moisture level of the seeds were measured by using 55 Wile Digital Moisture Meter.

Weevil exit hole : Exit hole were counted based in number of holes made by weevil. There were one or more than one hole in a grain. Damage and exit hole were found different. Damage was identified as just white color lining on grain whereas exit holes were found clearly round circle hole in boyh sided.

Germination or seed viability test : For germination test, 100 seeds of maize were kept in jute bag soaked in water and kept in laboratory. Then after 5 days, viability of seeds were calculated in percentage as follows;

$$\text{Seed viability\%} = \frac{\text{No. of viable seeds}}{\text{Total no. of seed}} \times 100$$

The data were tabulated in MS Excel, analyzed by using R-STUDIO software, and mean comparisons performed by DMRT at 5% and 1% level of significance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

EFFECT OF TREATMENTS ON MAIZE GRAIN DAMAGE IN STORAGE

Different doses of A. calamus rhizome powder treatments were significant (p<0.05%) from the control at 150 days (Table 1). The lowest grain damage was in A. calamus powder treated grains @ 5gm/kg (3.46%) and highest in untreated control (7.07%) after a month. At 150 days, it was lowest in maize grains treated @ 15gm/kg (1.93%), and the highest damage was in untreated maize grains (12.68%).

Table 1. Effect of treatments on maize grain damage by *S. zeamais* in Entomology Laboratory, NMDP, Rampur, Chitwan, 2016

Treatment	Grain damage (%) at indicted date	
	30 DAT	150 DAT
Acorus calamus 2.5gm/kg	3.54^{b} ±0.30 (1.88)	2.52^{b}±1.17 (1.50)
Acorus calamus @5gm/kg	3.46^{b}±0.70 (1.84)	3.13^{b}±1.20 (1.69)
Acorus calamus @10gm/kg	5.72^{ab} ±0.60 (2.38)	2.09^{b}±0.59 (1.41)
Acorus calamus @15gm/kg	4.06^{ab}± 0.41 (2.01)	1.73^{b}±0.69 (1.23)
Acorus calamus @20gm/kg	5.51^{ab}±1.62 (2.28)	2.30^{b}±0.12 (1.51)
Malathion@ 2gm/kg	5.67^{ab}±0.58 (2.37)	2.44^{b}±0.87 (1.51)
Control (untreated)	7.07^{a}±1.56 (2.63)	12.68^{a}±5.18 (3.41)
F test (α=0.05)	S	S
CV%	16.62	36.81
$LSD_{0.05}$	0.64	1.13
SEM	0.13	0.41

The figures in parenthesis indicate (√x+0.5), transferred values and ± indicate standard error. The same letter in each column is not significantly different by DMRT at 0.05 level; DAT = Days after treatment; S=significant.

EFFECT OF TREATMENTS ON MAIZE GRAIN WEIGHT LOSS IN STORAGE

Maize grain weight loss also significantly differed among the treatments (Table 2). The lowest weight loss was in A. calamus rhizome powder treated maize grains and highest in untreated maize grains.

Table 2. Effect of treatments on maize grain weight loss by *S. zeamais* in Entomology Laboratory, NMRP, Rampur, Chitwan, 2016

Treatment	Grain weight loss (%) at indicted date	
	30 DAT	150 DAT
Acorus calamus 2.5gm/kg	0.44^{b}±0.03 (0.66)	0.31^{b}±0.14 (0.53)
Acorus calamus @5gm/kg	0.42^{b}±0.08 (0.64)	0.39^{b}±0.15 (0.59)
Acorus calamus @10gm/kg	0.71^{ab}±0.07 (0.84)	0.26^{b}±0.07 (0.50)

Acorus calamus @15gm/kg	0.50^{ab}±0.05 (0.71)	0.21^{b}±0.08 (0.43)
Acorus calamus @20gm/kg	0.68^{ab}±0.20 (0.80)	0.28^{b}±0.01 (0.53)
Malathion@ 2gm/kg	0.70^{ab}±0.07 (0.83)	0.30^{b}±0.10 (0.53)
Control (untreated)	0.88^{a}±0.19 (0.92)	1.58^{a}±0.65 (1.20)
F test (α=0.05)	S	S
CV%	16.70	36.18
$LSD_{0.05}$	0.22	0.40
SEM	0.01	0.05

The figures in parenthesis indicate (√x+0.5), transferred values and ± indicate standard error. The same letter in each column is not significantly different by DMRT at 0.05 level; DAT = Days after treatment, S=significant.

EFFECT OF TREATMENTS ON MAIZE GRAIN MOISTURE

Moisture contents of grains also significantly varied among the treatments at 30 and 150 days after treatments due to laboratory environment (Table 3). There was lowest moisture 15.60% and 15.63% on Malathion @ 2gm/kg and higher moisture content on untreated maize grains at 30 and 150 days after treatment respectively.

Table 3. Effect of treatments on moisture content of maize grains due to *S. zeamais* in Entomology Laboratory, NMDP, Rampur, Chitwan, 2016

Treatment	Moisture content (%) at indicted date	
	30 DAT	150 DAT
Acorus calamus 2.5gm/kg	16.00^{ab}±0.15	16.00^{abc}±0.20
Acorus calamus @5gm/kg	16.16^{a}±0.08	15.70^{bc}±0.15
Acorus calamus @10gm/kg	16.10^{a}±0.09	16.13^{abc}±0.29
Acorus calamus @15gm/kg	15.80^{ab}±0.11	15.96^{abc}±0.13
Acorus calamus @20gm/kg	16.20^{a}±0.09	16.36^{ab}±0.32
Malathion@ 2gm/kg	15.60^{b}±0.20	15.63^{c}±0.13
Control (untreated)	15.80^{ab}±0.15	16.56^{a}±0.12
F test (α=0.05)	S	S
CV%	1.48	2.24
$LSD_{0.05}$	0.41	0.63
SEM	0.05	0.12

The figures in parenthesis indicate (√x+0.5), transferred values and ± indicate standard error. The same letter in each column is not significantly different by DMRT at 0.05 level; DAT = Days after treatment; S=significant

EFFECT OF TREATMENTS ON WEEVIL EXIT HOLE ON MAIZE GRAINS

Treatments were significantly different at 30 and 150 days after treatments (Table 4). Weevil exit holenumber was the lowest (2.66) at 150 DAT in malathion powder @ 2gm/kg treated maize grains but was at par with all doses of A. calamus rhizome powder treated seeds. The highest number of exit hole made by weevil was recorded on grains without any treatment (control).

Table 4. Effect of treatments on number of exit hole on maize grains due to *S. zeamais* in Entomology Laboratory, NMDP, Rampur, Chitwan, 2016

Treatment	Exit hole (No) at indicted date	
	30 DAT	150 DAT
Acorus calamus 2.5gm/kg	3.00^{b}±0.57 (1.71)	3.66^{b}±1.20 (1.86)
Acorus calamus @5gm/kg	2.33^{c}±0.33 (1.52)	5.00^{b}±1.52 (2.16)
Acorus calamus @10gm/kg	5.00^{a}±0.73 (2.15)	4.33^{b}±0.88 (2.06)
Acorus calamus @15gm/kg	3.00^{b}±0.57 (1.71)	4.00^{b}±1.73 (1.88)
Acorus calamus @20gm/kg	3.66^{b}±0.33 (1.91)	4.00^{b}±1.00 (1.97)
Malathion@ 2gm/kg	5.33^{a}±0.33 (2.30)	2.66^{b}±1.20 (1.55)
Control (untreated)	5.33^{a}±2.02 (2.21)	36.66^{a}±12.44 (5.88)
F test (α=0.05)	S	S
CV%	22.21	34.30
$LSD_{0.05}$	0.73	1.49
SEM	0.18	0.72

The figures in parenthesis indicate (√x+0.5), transferred values and ± indicate standard error. The same letter in each column is not significantly different by DMRT at 0.05 level; DAT = Days after treatment; S=significant

EFFECT OF TREATMENTS ON GERMINATION OF MAIZE GRAINS

No significant differences (p<0.05) occurred on maize grains germination among the different treatments at 30 and 150 days after treatments (Table 5). Usually the germination percent was lower at 150 days as compared to 30 days after treatment, and the lowest germination percent was recorded on untreated maize grains at both 30 and 150 days after treatment.

Table 5. Effect of treatments on germination of maize grains in Entomology Laboratory, NMDP, Rampur, Chitwan, 2016

Treatment	Maize grain germination (%) at indicted date	
	30 DAT	150 DAT
Acorus calamus 2.5gm/kg	53.33 ±5.24 (7.29)	49.00±5.50 (6.97)
Acorus calamus @5gm/kg	59.33±3.84 (7.70)	54.33±3.75 (7.36)
Acorus calamus @10gm/kg	53.00±11.01 (7.20)	59.66±1.20 (7.72)
Acorus calamus @15gm/kg	61.00±6.80 (7.79)	57.66±1.76 (7.59)
Acorus calamus @20gm/kg	54.66± 6.84 (7.36)	58.66±5.04 (7.64)
Malathion@ 2gm/kg	60.66± 3.48 (7.79)	55.00±2.00 (7.41)
Control (untreated)	56.00± 2.89 (7.48)	48.66±6.11 (6.94)

F test (α=0.05)	NS	NS
CV%	9.79	6.58
$LSD_{0.05}$	-	-
SEM	0.54	0.23

The figures in parenthesis indicate (√x+0.5), transferred values and ± indicate standard error. The same letter in each column is not significantly different by DMRT at 0.05 level; DAT = Days after treatment, NS= non-significant

DISCUSSION

Botanical material- *Acorus calamus* (L.) rhizome powder @ 15gm/kg for maize grain treatment was effective for the control of *Sitophilus zeamais* Motschulsky under laboratory condition in comparison to other doses. Although, Malathion was also effective but it cannot be used in maize grains for human consumption. Grain weevils have also been found to be resistant to DDT and phoxim as well as to both Malathion and pirimiphos-methyl (Sayaboe and Aceda, 1990), and to pyrethroids (Fragoso *et al*., 2003; Ribeiro *et al*., 2003). Due to the development of pesticide resistance and human health hazard, it was necessary to search alternatives for store pest management. Certain concentration of *A. calamus* has been found even more effective than Malathion in controlling *S. oryzae* in wheat seed storage (Panthee, 1997). Sweet flag, *A. calamus* is a herb, which does not have any negative effect on human health and environment. It is easily available at the local premises, and is likely to be accepted by the farmers (Panthee, 1997).

CONCLUSION

This study was carried out at NMRP, Rampur, Chitwan from June to November, 2016. To improve the post-harvest quality of maize and reduction of weevil infestation, botanical materials- *Acorus calamus* (L.) rhizome powder @15gm/kg maize grain treatment was effective for the control of maize weevil (*Sitophilus zeamais* Motschulsky) under laboratory storage condition. Due to limitation of time the research was conducted for only 5 months. So, further research should be done for longer duration and in different agro-ecological zones as well.

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RELATIVE EFFICIENCY OF ORGANIC TEA PRODUCTION IN ILAM, NEPAL

Shiva Chandra Dhakal[1] and Khem Raj Dahal[2]

ABSTRACT

Conventional farming systems have been widely creating problems in terms of pollution of agricultural environment and questioning on its sustainability. In this context a study was carried out in Ilam district of Nepal for measuring efficiency of organic tea production over conventional system. Farm level production data were collected using pretested semi-structured interview schedule administered to 60 randomly selected tea producers. Collected data were analyzed for average of cost, return and profitability using STATA-12. Physical yield of tea was lower in organic system relative to conventional system. In terms of average cost of production, organic production crossed conventional one and support of premium price for organic tea was insufficient to recover excess cost of production of organic tea. Organic farms face many more barriers than conventionally cropped farm especially unavailability of organic packages of production. In this context, technological alternatives such as suitable bio-fertilizers, vermi-compost, use of machineries and improved farm yard manure would improve productivity and profitability of organic tea production.

Key words: Conventional farming, cost, organic farming, productivity, profitability, tea

INTRODUCTION

Nepal launched different programs for agricultural intensification in the 1960s following green revolution in neighboring countries. This has increased indiscriminate use of agrochemicals with consequent result in pollution of water, air and soils and also contributed to health hazards and economic losses (Pokharel and Pant, 2008; Bhatta and Doppler, 2011). In this context, it is useful to consider what agricultural practices may ensure food security and better livelihoods, while keeping the environment healthy. Organic farming is a widely discussed alternative farming system and represents a growing niche market in many countries (Charyulu and Biswas, 2010).Organic farming claims to have the potential to provide such benefits in the form of environmental protection, conservation of nonrenewable resources and improved resource use efficiency and food quality (Schnug *et al.*, 2006; Sreenivasa, 2012). Most importantly, organic farming enhances biodiversity offering higher nutrient cycling and mineralization, better microclimatic regimes, which further reduces the risks borne by farmers.

Organic agriculture is often criticized for lower yields in comparison to conventional agriculture (Muller, 2009). Studies conducted in different countries have shown that there is often a decline in production when conventional farms are converted into organic farms, with gradual increases over a period of time (Ricker, 1997).Avoidance of synthetic fertilizers in organic agriculture often results in lower yields per land unit. For instance, Lotter (2003) reported a 10–15% yield reduction in production in organic agricultural systems relative to conventional agriculture in East Africa.

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Similarly, Badgley *et al*. (2007) fond average yield losses in North American and European developed countries due to a shift from chemical means of nutrient management and plant protection to organic management to be in the range of 0–20%. For perennial crops, such as coffee or banana, high yield reductions are more likely, even though higher yields were reported in some cases (Pulschen and Lutzeyer, 1993; Polius, 2000). Reinforcing such results, conventional farms were found significantly more efficient than organic farms in Italy (Madau, 2007).

About 1.8 million farmers in 162 countries grow organically on more than 37 million hectares of agricultural land worldwide (FiBL and IFOAM, 2013). Given the global trends in organic farming, this research paper has tried to answerefficiency of organic farming with focus on tea production in Nepal. Relative efficiency of organic tea production over conventional tea production was measured in terms of cost, return, productivity and profitability. So, this research compared organic and conventional tea production practices to understand differences in outputs and profits under different challenges faced by conventional tea producers with relevant suggestions.

METHODOLOGY

Data for this study were gathered from a primary survey of organic and conventional tea producers in Ilamdistrict of Nepal. Fikkal Village Development Committee (currently Fikkal Rural Municipality) was purposively selected for the study due to availability of sufficient numbers of tea growers in both categories of the study. Thirty farmers from each category were selected randomly from the area using simple random sampling technique. Field surveys were conducted to collect primary data in January 2012 using semi-structured pretested interview schedule. Collected data were entered in SPSS and analyzed using STATA-12.

Different forms of productivity were measured in the study: a) yield or quintals of physical output per hectare; b)labour productivity orRupees of output per man-day; c) the monetary value of output per rupee of input cost, including the expenses on labor, and d) the monetary value of output per Rupee of input cost, excluding expenses on labor. The first measure is the physical relation between output and land size. The second measure describes productivity in monetary terms per unit of labor. This was used because in subsistence agriculture, where labor is the main input and family labor is generally the only type of labor used, the returns to labor is important. The third measure estimates productivity in monetary terms per unit of all forms of cost incurred. The last productivity indicator measures productivity in monetary terms per unit costs, excluding expenditure on all the types of labor, whether family or hired.

Costs are made up of five components. Labor cost was estimated as the sum total of hired labor expenses and the imputed value of own human labor used in the production. Labor time was valued at the prevailing local wage rate i.e. Rs.250 per day in the study year. Expenses on organic manure included expense on purchased and home produced farm yard manure, green manure, oil cakes, poultry manure and compost, valued at prevailing market prices. Expenses on chemical fertilizers cover the outlay incurred on all conventional fertilizer inputs. Expenses on plant protection chemicals include the total outlay made on organic and/or conventional pesticides and or materials cost required to purchase the raw materials. This covers expenses on conventional insecticides, fungicides, rodenticides, tobacco, cow dung, *neem* leaves and other plant materials required to prepare bio-pesticides. Expenses on transport incurred by the producer, electricity and any hired machinery costs were pooled into a single item. Thus, the average cost of production, which is the sum of these five components, is calculated as: 1) Average Cost 1 (Rs./qt) = Total cost (Rs.)/Total production (qt); and 2) Average Cost 2 (Rs./ha) =Total cost (Rs.)/ Total Area under cultivation (ha). Farm income was then estimated by valuing the main and by-products of crops at their prevailing market prices. Profit was then estimated as the difference between the gross income and total cost. Profit 1 was calculated on a per hectare basis and Profit 2 was estimated on a per quintal basis so that the profit is comparable with the price of the output. The details of the efficiency measurement indicators and their illustration are presented in Annex 1.

RESULTS

Farmers were growing organic tea on an average of 0.99 ha which is higher by 0.44 ha as compared to conventional system of production. Productivity of conventional tea was higher than organic tea productivity by 24 qt/ha in study area. The scenario of gross crop income was also similar in line with lower yield of organic tea production. Gross farm income of organic farming was inferior as compared in conventional system and it was lower by Rs. 23777 per hectare. This was because of the lower productivity and insufficient premium price received by the organic tea producers for the better quality tea of organic system. The amount of price premium received by organic tea producers was Rs. 3016 per quintal. All these parameters on study about economic statement of organic and conventional tea production are depicted in Table 1.

Table 1. Average economic statement of tea production in organic and conventional system

Particulars	Production type		Mean difference
	Conventional	Organic	
Area (ha.)	0.55	0.99	-0.44**
Yield (qt/ha)	40	16	24*
Gross income (Rs./ha)	110575	86798	23777
Price (Rs./quintal)	2477	5493	-3016*

* indicates 1 per cent level of significance and ** indicates 5 percent level of significance in t-test for mean differences.

Farmers noted difficulties to pluck organically produced tea leaves in comparison to conventional farming, where new growth is succulent and easy to pluck. This has caused higher labor cost for organic tea production by about Rs. 8159 per hectare. Against this the cost on organic manures was lower in organic farms by about Rs. 5387 per hectare (Table 2). This was because of unavailability of market to purchase sufficient organic manure in the study district for applying in relatively larger size of organic farms. While production costs of conventional tea, in terms of fertilizers and pesticides are higher, this was offset by higher labor costs in organic production.The price premium for organic tea did not make up for the high cost of production and there is no significant differences in profits.

Table 2. Average level of different cost items in organic and conventional tea production system

Particulars	Production type		Mean difference
	Conventional	Organic	
Labor cost (Rs./ha)	46669	54828	-8159**
Labor use (manday/ha)	187	219	-32**
Organic manure (Rs./ha)	17114	11727	5387
Chemical fertilizer(Rs./ha)	1329	0	1329*
Plant protection chemical (Rs./ha)	2410	1088	1322**
Transport and electricity (Rs.)	9203	4086	5117*

* indicates 1 per cent level of significance and ** indicates 5 percent level of significance in t-test for mean differences

Average cost on per hectare and per quintal basis, labor productivity, profit and productivity were estimated and compared between organic and conventional system of tea production and depicted in Table 3. In terms of average cost on per hectare basis organic farms exceeds conventional farms but appeared non-significant. But, average cost of tea production on per quintal basis was found significantly higher for organic farms as compared to conventional farms by Rs. 3525.Labor productivity, profit and productivity of factors of production are higher in conventional type of farming but appeared non-significant. Productivity measured as the ratio of value of output to value of all input variable cost including labor or benefit cost ratio in other words was 1.74 for conventional farming and 1.22 for organic farming. This clearly showed the better profitability of conventional tea production system over organic production system in spite of price premium achieved by organic tea growers. This was because of lower productivity and higher labor cost of organic tea production system.

Table 3. Average cost, productivity and profit of tea production in organic and conventional system

Particulars	Production type		Mean difference
	Conventional	Organic	
Average cost 1 (Rs./ha)	63469	71048	-7579
Average cost 2 (Rs./quintal) *	2105	5630	-3525*
Labor Productivity (Rs./man day)	546	399	147
Profit 1 (Rs./ha)	47107	15774	31363
Profit 2 (Rs./qt)	371	-136	507
Productivity 1 (value of output/ input cost including labor)	1.74	1.22	0.52
Productivity 2 (value of output./ input cost excluding labor)	13.00	7.00	6.00

* indicates 1 per cent level of significance in t-test for mean differences

CONCLUSION

Conventional tea has higher yields with little difference in profits when compared to organically produced tea. The average cost of tea production was found higher in organic production systems than in conventional system. In this context, it would be useful to invest in expanding technological alternatives such as more suitable bio-fertilizers, vermi-compost, capital intensive mechanical technologies and commercial production of organic manures. In the case of organic tea, as the plucking takes relatively longer due to stiffness of the flushes as compared to that in conventional system, promotion of mechanical plucking could be considered. Farmers suggest that there is a shortage of organic manure, inhibiting its efficient use in both types of farms. This could be overcome by promoting livestock enterprises. If this accompanied by improved farm yard manure (FYM) management and compost preparation with incorporation of weeds, crop residue and forest leaf litters, it is possible for organic manure substitute conventional chemical fertilizers. In addition to these technical aspects, raising awareness among the producers, consumers and planners is essential for increasing the scale of operation, demand for organic products and sustainability of the production system.

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The authors are grateful to South Asian Network for Development and Environmental Economics (SANDEE) for providing financial support to carry out this study. Authors would like to wish their gratitude to all respondents under study for providing their valuable time and information required for study. We would like to thank all enumerators and organizations for their contribution in data collection.

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Annex 1. Description of variables used in efficiency measurement of tea

Name of variable	Description
Area (ha.)	Average net area under cultivation of a selected crop by a household in a year.
Yield (qt/ha)	Physical output of main product of the crop divided by area.
Gross income (Rs./ha)	Total gross value of a crop valued at the prevailing market price per hectare
Price (Rs./quintal)	Market price of the main product of the selected crop per weight in quintals
Labour cost (Rs./ha)	Total labour cost incurred in cultivation of the selected crop calculated by valuing the family and hired human labor at the prevailing market wage rate.
Expenses on organic manure (Rs./ha)	Total expenses on farm yard manure, poultry manure, compost, bio fertilizer and vermi-compost valued at prevailing market prices.
Expenses on chemical fertilizer (Rs./ha)	Total monetary expenses on all the forms of chemical fertilizers purchased by farmers for applying to the selected crop under cultivation.
Expenses on plant protection chemicals (Rs./ha)	Total expenses on purchase and preparation of all the forms of organic and conventional plant protection chemicals.
Expenses on transport, electricity, seed and others (Rs.)	Total expenses on transport, electricity, seed and other includes cost on gunny bags, loading and unloading charge, snacks etc.
Average cost 1 (Rs./ha)	Total cost incurred to cultivate a hectare of land for the selected crop
Average cost 2 (Rs./quintal)	Total cost incurred to produce a quintal of the selected crop.
Labor Productivity (Rs./man day)	Total value of output contributed per man day of human labor.
Variable cost (Rs.)	The total of cost incurred in variable inputs such as seed, fertilizer, human labor, irrigation etc. (11* Average no of ha cultivated)
Profit 1 (Rs./ha)	Gross income (3) minus variable costs (11) incurred in production of a crop per hectare.
Profit 2 (Rs./qt)	Gross income minus variable cost incurred in production of a crop per quintal of product.
Productivity 1 (value of output/ input cost including labor)	Total value of output per input cost, including labor
Productivity 2 (value of output./ input cost excluding labor)	Total value of output per rupee of input cost, excluding labor.

IMPACT OF KISHAN CALL CENTER FOR SOLVING FARMERS' PEST PROBLEMS IN AGRICULTURE

Resham Bahadur Thapa[1], Nirajan Belbase[2] and Shiv Yendyo[3]

ABSTRACT

With an objective to assess the impact of Kishan Call Centers (KCC) for solving pest problems and crop loss in farmer's field, a survey was conducted among randomly selected beneficiary farmers by using personal interview through semi-structured questionnaire via phone calls in 2017. Data for 2016 received from KCC operated by AgriCare Nepal Pvt. Ltd., Yagyapuri, Chitwan were also analyzed by using MS-Excel 2010. All respondents were literate with 76 percent male and 24 percent female of middle age categories engaged in commercial agriculture in their own lands cropping 10-20 ropani of cropping area and earning 5-10 lakhs rupees/annum. About 78 percent of farmers reported pest problems in KCC and the majority of problems were pathological followed by entomological, nutrient deficiency and others. Over three-fourth of beneficiary farmers were highly satisfied indicaing positive impact of KCC in Nepalese agriculture. Hence, there should be sufficient KCC numbers and extension of KCC services to foster extension of new technologies.

Key words: Agriculture, Insect pests, kishan call center, plant diseases

INTRODUCTION

Nepal is predominantly agricultural landlocked country. Geographically, it is divided into three distinct belts: the mountain (35%) in the north, the hills (42%) in the middle and low land terai (23%) in the south. About 65.5 percent population is estimated involved in agriculture for their livelihoods (MoAD, 2015). Thus, about two-third of the Nepalese people depend on agriculture sector, which contribute nearly one-third GDP of the country (MoAD, 2017). This indicates that agriculture is the backbone of national economy. Agricultural crops suffer due to harmful insect pests, disease, nematodes, rodents from time immemorial (PPD, 2016).

Outbreak of insect pests and disease is common phenomena in commercial agriculture. However, rural farmers have limited access to improved seeds, new technologies, market opportunities especially immediate technical supports in pest management. To solve farmers' problems, continuous two-way interaction among the farmers, agricultural scientists and extension personnel is the most critical missing component of agricultural extension (Saravanan, 2010). One-to-all contact via extension services is practically difficult and a shift towards the group approach is becoming inevitable for speedy transmission of technology and latest technical updates to farmers, for resolving their diverse problems. In this line, Agri-Care Nepal Pvt. Ltd. launched Kisan Call Center (KCC) in 2012 at Yagyapuri-Bharatpur, Chitwan to deliver agriculture extension services to the farming community. The purpose of this KCC is to respond to issues raised by farmers instantly at the local level. This Call Center based on Chitwan, tries to handle farmers' problem from any

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part of the country. Queries related to agriculture and allied sectors are being addressed through this Call Center. Therefore, now a farmer from any part of the country can contact the KCC by dialing the toll free Telephone No. 1660-5652-999 and report their problems/queries related to farming. The operator at the KCC attempts to answer the problems/queries of the farmers immediately. If the operator at the Call Center is not able to address the farmer's query immediately, the call is being forwarded to agricultural specialists working at Agriculture and Forestry University (AFU), Chitwan or Nepal Agriculture Research Council (NARC) and solution sent to the farmer immediately. This study attempted to assess the impact of KCC to solve the ever increasing problems of pests in farmer's fields.

METHODOLOGY

After reviewing the available literature related to the study, a scientific and systematic procedure was developed and adopted for conducting the investigation following survey methodology (Kothari, 2007). KCC, Yagyapuri, Chitwan was selected; the reason behind the selection of KCC from AgriCare Nepal Pvt. Ltd, Yagyapuri, Chitwan are: i) Few number of KCC operated in Nepal, and researcher belongs to Chitwan, so it was easier to study; ii) This KCC has been operating since 2012, and therefore, its coverage and availability is well extended throughout the country; iii) There has been no research to assess impact of KCC on Agriculture, and iv) Familiarity of the researcher with the area to elicit information. Random sampling method was used for selecting sample from the calls received at KCC throughout the year of 2016.

Out of total calls received in 2016, 100 calls were randomly selected, farmers were contacted with the help of Agri-portals staffs through telephone from different parts of Nepal, and necessary information gathered, which were categorized into different agricultural problem wise (disease/insect pest problems, nutrient deficiency, farming technology, and general information) including 50 commercial farmers' basic social information. The pathological problems were further categorized as fungal, bacterial and viral disease and evaluated impact of KCC on pest management in agriculture. Secondary data was collected from several literatures, such as books, journal articles, and annual reports available at different academic and non-academic institutes etc. Thus, collected data were entered in MS Excel format in computer. Then the descriptive interpretation of the study was done by preparing suitable tables, charts and figures.

RESULTS AND DISCUSSION

SOCIO-ECONOMIC INFORMATION

Since use of Information and Communication Technology (ICT) is influenced by socioeconomic conditions of the farmers, the study initially focused on such factors.

GENDER DISTRIBUTION

For this, 50 farmers were interviewed. Figure 1 describes the participation of gender in the study. Accordingly, 76 percent were male and 24 percent were female. This shows that use of phone calls by female to KCC is quite lower than the male.

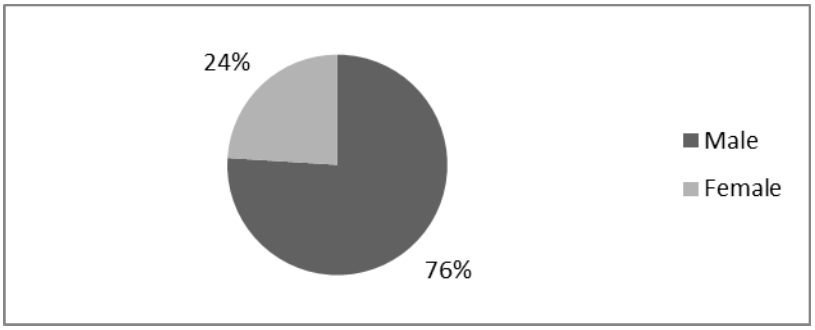

Figure 1. Gender distribution of respondent farmers

Savitharamma (2011) reported in the study conducted on "Formative Evaluation of Kisan Call Center in Tamil Nadu" that almost all of the calls (99.62%) were made by men. It is well known that in rural society, male has higher exposure to external situations than female. Even though female have more involvement in agriculture and allied fields still male always prefer to utilize new technologies and innovative approaches in transfer of technology due to their exposure to the outside world. Mishra (2008) and Verma (2008) also reported similar findings.

AGE DISTRIBUTION

Age determines the maturity of an individual in terms of thinking, experience and exposure and these affect the mobility, energy level and decision making capability of a person. The age wise distribution of the respondents is presented in Table 1.

Table 1. Age distribution of the respondents

SN	Age group	Frequency	Percent
1.	Up to 30 years (young age group)	12	24
2.	31-50 years (middle age group)	32	64
3.	Above 50 years (old age group)	6	12

It was found that, more than half (64%) of the KCC users belonged to middle age group, nearly one-fourth (24%) of them belonged to the young age group and a little more than one-tenth of the respondents (12%) to the old age group. The farmers of the middle age group had more participation in ICT.

Middle age group or youths are supposed to be more technology adopter and can make better use of selected Agri- portals for agricultural development. The findings of the study are in harmony with the observation of Chauhan (2010).

EDUCATION STATUS:

Among 50 farmers interviewed only 4 percent were literate; 28 percent had primary education (grade 1-5), 38 percent had secondary level education (grade 5-10), 22 percent higher secondary (grade 11-12) and only 8 percent graduate (bachelor) and above (Figure 2). So it was concluded that most of the farmers, who used to solve problems related to their farming through KCC had secondary level education followed by primary level education. According to Jaisridhar (2013), in study of 150 KCC beneficiaries vs 150 non-beneficiaries, KCC beneficiaries had better educational status.

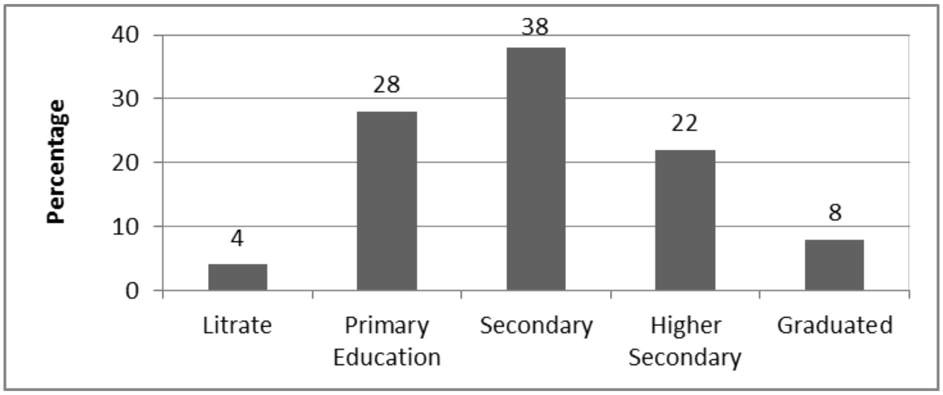

Figure 2. Education status of the interviewed farmers

LAND OWNERSHIP

Among the 50 respondents, 68 percent were farming on their own land, 24 percent of the respondents were farming on own and leased lands and 8 percent of respondents farming on leased land only for their livelihoods (Figure 3). It indicates that most of the farmers had own land to cultivate crops. Similarly, the operational landholding and ownership was better of KCC beneficiaries than non KCC beneficiaries (Jaisridhar, 2013).

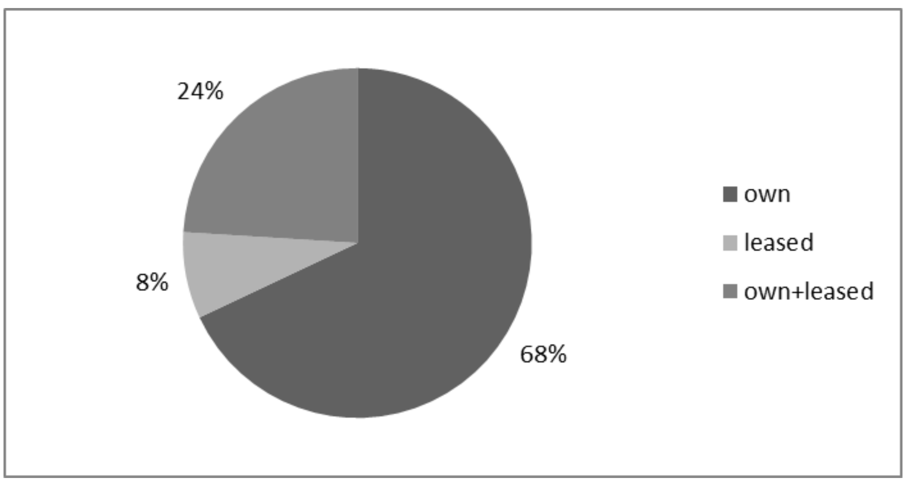

Figure 3. Land ownership status of respondents

INCOME STATUS

Among the selected respondent farmers, 18 percent farmers were earning up to Rs. 5 lakhs annually, 44 percent were earning between Rs. 5 to 10 lakhs annually, 22 percent were earning between Rs. 10 to 20 lakhs yearly and the rest 16 percent were earning above Rs. 20 lakhs annually (Figure 4). This shows that farmers whose income status is between Rs. 5 to 10 lakhs yearly were frequently in touch with ICT via KCC. In as similar study in livestock, around 63 percent of the beneficiaries expressed their medium level of gratification towards KCC for minimizing their time and cost (Jaisridhar, 2013).

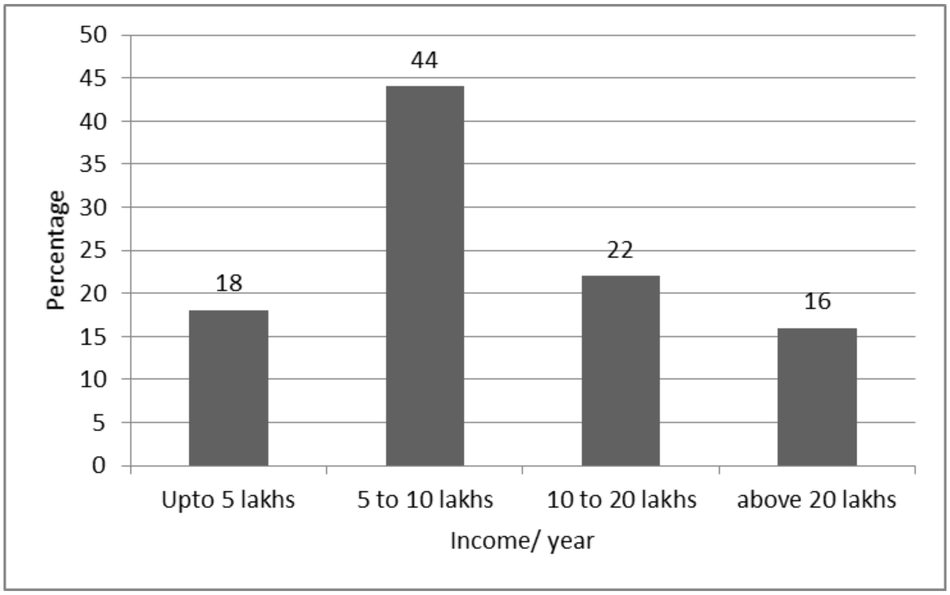

Figure 4. Income status of respondent farmers

LANDHOLDING STATUS

Among the interviewed farmers, 46 percent cultivated 11-20 ropani, 24 percent cultivated above 20 ropani, 16 percent cultivated 5-10 ropani and 14 percent cultivated less than 5 ropani of land (Figure 5). Jaisridhar (2013) reported that KCC beneficiaries had higher operational landholding.

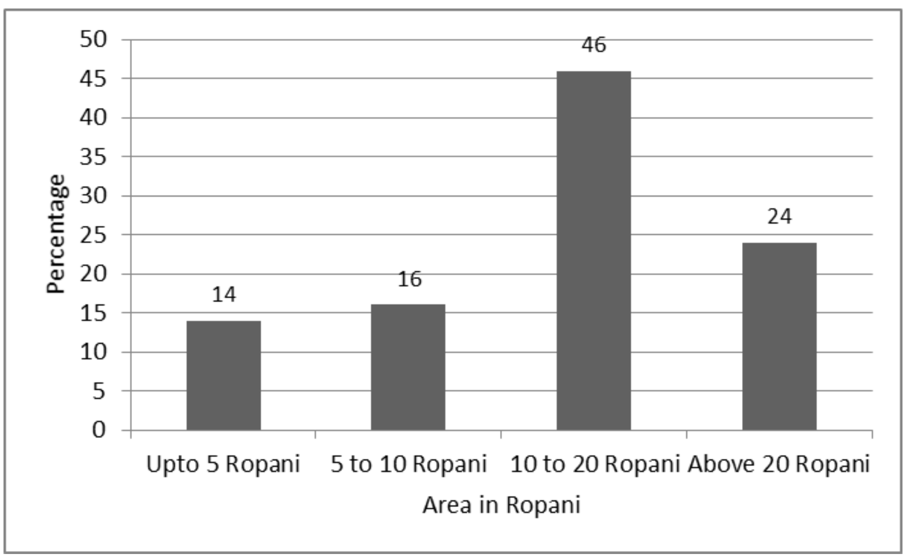

Figure 5. Land cultivation by the respondent farmers (20 ropani = 1 hectare)

OCCUPATION STATUS:

Occupational status was conceptualized as any activity in which a person was regularly engaged to achieve standardized award utilization. In this study, most of the respondents' occupation was agriculture but some of them were also engaged in other occupation along with agriculture. So, respondents are categorized as occupation having agriculture only and agriculture and other job (Figure 6).

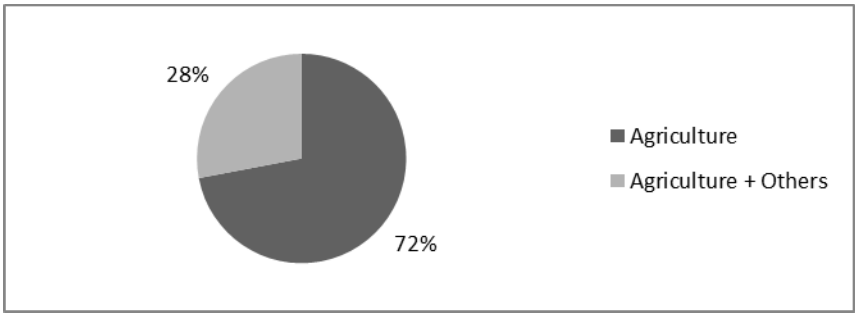

Figure 6. Occupation status of respondent's farmers.

The study was focused on farmers having agriculture as their main occupation.Hence, a very few respondents were service holder (3.61%) and other few were in business (1.20%). The results are in conformity with the findings of Sasidhar (2008).

CALL RECEIVED IN 2016

In the KCC, 4,288 calls were received from the farmers throughout the year of 2016. It shows that the extension service of KCC was at its good coverage and the calls were distributed through the year, i.e. January to December in the year 2016 (Figure 7). Slightly higher numbers of calls were received during January-February and October-November months. Jaisridhar (2013) reported that two-third of the KCC respondents (66.67%) and less than half of the non-beneficiaries (46.67%) had high information utilization.

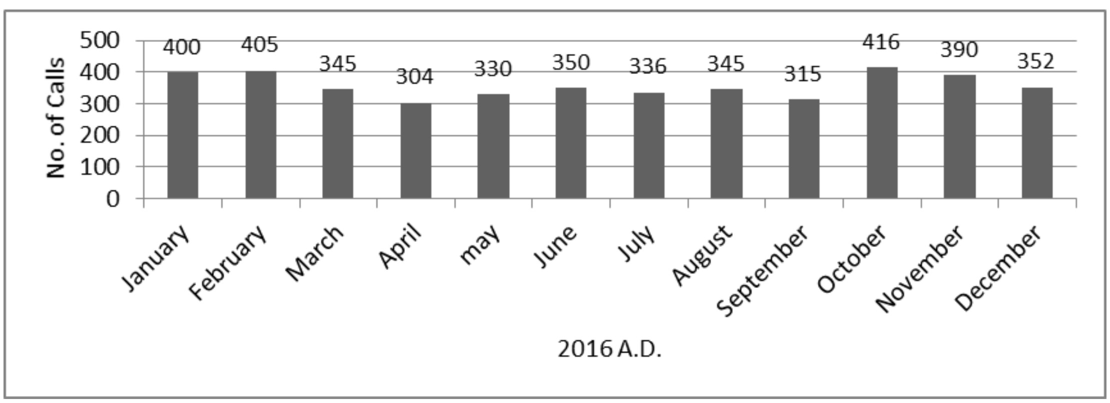

Figure 7. Farmer's calls received in KCC during the year 2016

PROBLEMS CATEGORIZATION

Among the 100 calls selected by random sampling method from the total calls received in 2016 were categorized into disease pest problems, cultivation practices, nutrient deficiency problems and general information. The Figure 8 shows that over three-fourth of the respondents were facing pest problems, i.e. nearly eight - tenth of the farmers call received by KCC was pest problems on their crop field.

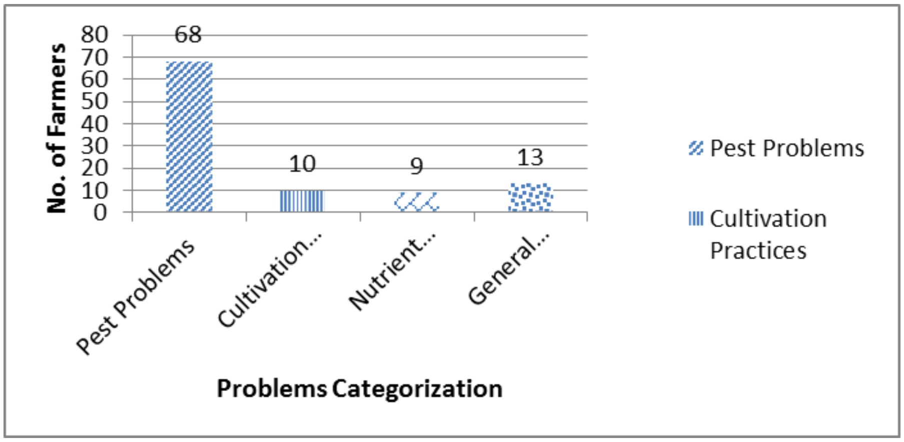

Figure 8. Problems categorization of farmers

Narayanswamy et al. (2005) reported that most of the queries to the center were related to vegetable and fruits. About 21 percent of the respondents raised queries related to pest and diseases followed by market information in India. Similarinformation are available among the calls received from the agriculture sector, the maximum calls being related to plant protection followed by production techniques, marketing of farm production, high-yielding variety seeds, weather forecasting and others.

PEST CATEGORIZATION

Further categorization of pest problem into entomological and pathological aspects revealed that over two-third of the problems were categorized as pathological problems (Figure 9).

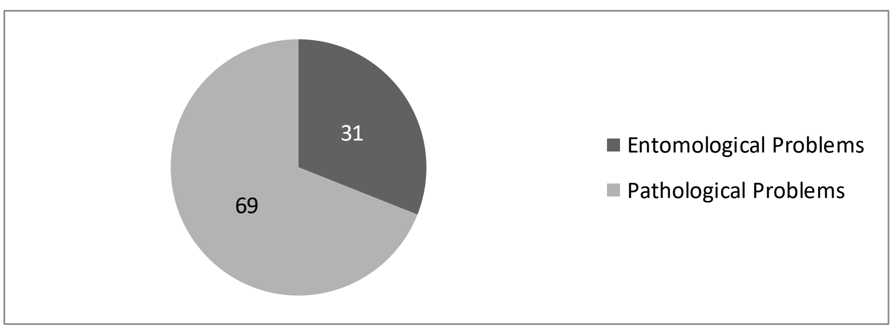

Figure 9. Farmer's pathological and entomological problems

Common disease problems: Interview shows that different fungal, bacterial and viral diseases were common in the farmer's field. Among them, most common disease problems faced by the respondents in their crop fields are presented in Table 2.

Table 2. Common disease problems faced by the respondents

Name of the disease	Causal organism	Common host plants.
Fungal disease		
Damping off	*Pythium spp.*	Seedlings of tomato, potato
	Phytophthora spp.	
	Fusarium spp. etc.	
Powdery mildew	*Erysiphe cichoracearum*	Cucurbits
	E. polygoni	Pea
Rust	*Puccinia graminis-tritici* (Black or stem)	Wheat
	P. recondita (brown or leaf)	
	P. striiformis (yellow or stripe)	
Downey mildew	*Pseudoperonospora cubensis*	Cucurbits
	Peronospora parasitica	Crucifers
	Peronospora viciae	Pea
Clubroot	*Plasmodiophore brassicae*	Crucifers
Fungal wilt	*Fusarium spp., verticillium spp*. etc.	Many vegetables.
Anthracnose	*Colletotrichum truncatum*	Soybean
Bacterial disease		
Bacterial wilt/brown rot	*Ralstonia solanacearum*	Potato
Bacterial blight	*Xanthomanas oryzae pv. Oryzae*	Rice
	Pseudomonas syringae pv. glycinea	Pulses
Black rot	*Xanthomonas campestis*	Crucifers
Ring rot	*Corynebacterium sepedonicum*	Potato
Viral disease		
Potato mosaic	*Potato mosaic virus X (PMVX)*	Potato
	Potato mosaic virus Y (PMVY)	
Potato leaf roll	*Potato leaf roll virus (PLRV)*	Potato
Tomato mosaic	*Tomato mosaic virus (ToMV)*	Tomato
Yellow vein mosaic of okra	*Yellow vein mosaic virus (YVMV)*	Okra
Tobacco mosaic	*Tobacco mosaic virus (TMV)*	Tobacco and vegetables

Among the pathological problems, over three-fourth of the problems (77%) were fungal diseases followed by about one-fifth viral (19%) and remaining bacterial problems (4%) (Figure 9).

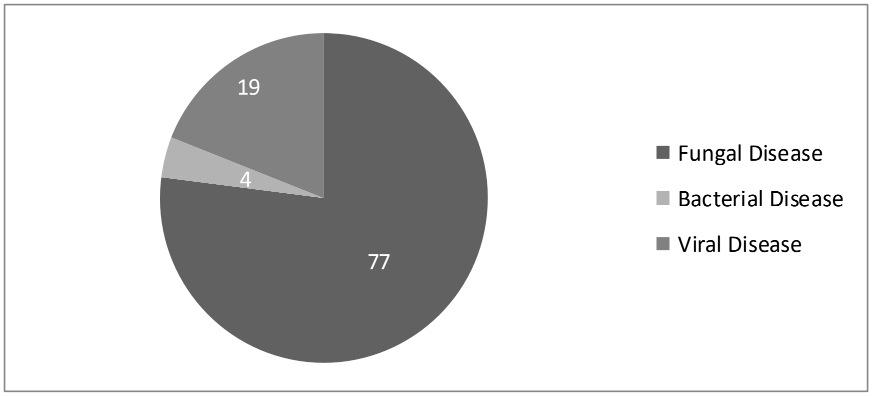

Figure 9. Pathological problems categorization based on fungal, viral and bacterial organisms

COMMON INSECT PEST PROBLEMS

Some of the insects were not recognized by farmers and from the interviewed respondent's common insect pests seen in farmers' field are listed in Table 3.

Table 3. Common insect pest problems faced by the respondents

Common name	Scientific name	Major host
Aphids	*Aphis gossypii* *Myzus persicae* *Lipaphis erysmi* *Brevicoryne brassicae*	Most of the fruits, vegetables and field crops
Thrips	*Thrips tabaci*	Most of the vegetables
White flies	*Bemisia tabaci*	Most of the vegetables
Cut worms	*Spodoptera lutera* *Agrotis segetum*	Most of the vegetables
Tomato Fruit Borer	*Helicoverpa armigera*	Tomato and other vegetables
Leaf minor	*Liriomyza huidobrensis*	Crucifers and other vegetables
Army worm	*Mythimna separata*	Most of the vegetables
Potato tuber moth	*Phthorimaea operculella*	Cabbage
Cabbage butterfly	*Pieris brassicae nepalensis*	
Tomato leaf miner	*Tuta absulata*	Tomato
White grub	*Phyllophaga spp,*	
Fruit fly	*Bactocera cucurbiteae*	Cucurbits
Red ants	*Dorylus orientalis*	Potato and other root crops

Purushothaman and Shailesh Kumar (2004) in their study indicated an effective extension tool in hills, and about 26 percent of the farmers intended to know about crop diseases, 25 percent about crop varieties, 12 percent about insect pests and 11 percent about seed availability. In another study by Savitharamma (2011) showed that the highest calls were related to diseases (23.77%)

followed by callsrelated to varieties andhybrids (12.52%). In the Nepalese context, over 80 percent of the farmers are having queries on pests than on other aspects of crop production (Thapa and Sharma, 2006). In addition, the suggestions offered by the beneficiaries were more information related to low cost technology followed by many KCCs for providing services to farmers.

TREATMENT EFFECTS

When farmers suffer from pest problems in their field they need immediate solution and they remember KCC to receive solution for their problems. The technologists reply them with definite solution and treatment through their knowledge bank or with the help of subject specialists and research scientists. Farmers immediately apply the recommended treatments or practices in their field. In this study through telephone interview, their replies on recommended treatment effect as good, fair, poor or no effect is presented in Table 4. Singh (2003) reported that 50 percent farmers were having medium level of mass media exposure and less than one third to low level (31%) with higher exposure and better utilization and effects.

Table 4. Farmers' responses on the KCC prescribed treatment effects

Treatment effects	Frequency	Percentage
Highly effective (Good)	34	68
Effective (Fair)	14	28
Less effective (Poor)	2	4

Among the 50 respondent farmers, 34 farmers replied that KCC's recommended treatment was highly effective (i.e. good), 14 farmers replied effective (i.e. fair), 2 farmers replied less effective (i.e.poor), and there was no farmers who replied treatment as ineffective (Figure 10). Here, viral problems were difficult to manage but KCC suggestions helped to minimize the problem, so they replied it as fair or even as good.

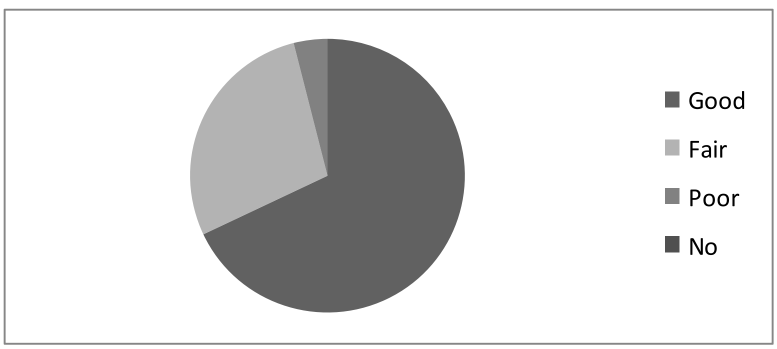

Figure 10. Farmers' queries and KCC's prescription effects on pest management

Selvarani (2005) found all of the respondents followed the recommendations offered through KCC accurately. More than one-third of the respondents (40%) expressed that instant solutions to the agricultural problems are offered through KCCs. Nearly half (46.67%) of the respondents made less than five calls to KCC to clarify their doubts. A little less than one-third of the respondents (30.00%) made 5-10 calls.

LEVEL OF SATISFACTION

In the study, the main aim was to assess farmers' satisfaction level offered by the new program to solve their problems, keep them aware, updated to the new technology developed and extended by KCC of AgriCare. Among the interviewed farmers, over three-fourth (76%) were highly satisfied, one-fifth (20%) satisfied and only a few (4%) were unsatisfied (Figure 11).

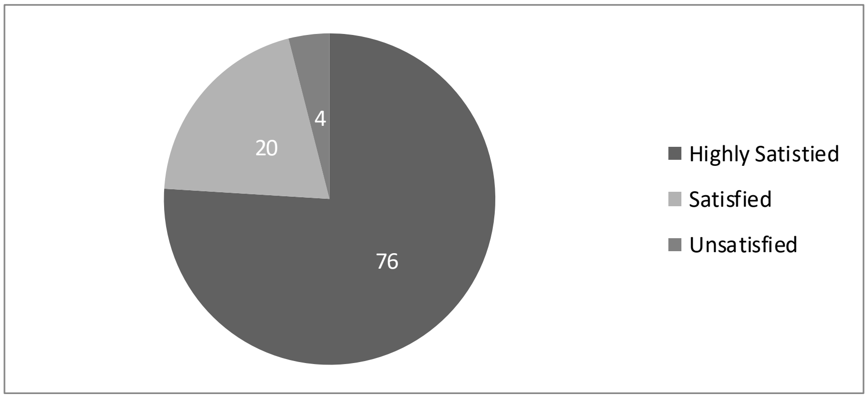

Figure 11. Farmer's satisfaction levels on KCC's recommendations

This study found highly positive impact and treatment effects from the services of KCC to pest management in agriculture. Niraula (2009) indicated that Information Technology has immense potential in enhancing the efficiency and effectiveness of agriculture extension programs, agricultural trade and dissemination of best agricultural practices. Naraula and Sharma (2008) revealed that private and public ICT model have been launched with agricultural applications to provide a range of services to fulfil the information deficit the farmers are facing in agricultural production, input-supply, agricultural extension, market information, intelligence and price discovery.

A study on evaluation of the impact of KCCs conducted by Administrative Staff College of India, Hyderabad revealed that 84 percent of the farmers expressed overall satisfaction regarding the advice provided to them by Call Center Agents. The study also pointed out that KCC advice resulted in effective control of pests, weeds and diseases and better management of fertilizer use. Advice given by KCCs enabled farmers to take timely decisions and during the process crop production and productivity increased. Large majority (90%) of the farmers was satisfied with the e-chaupal services. Farmers also appreciated the convenience of services, ease of accessibility of e-chaupal, credibility and reliability of information provided by e-chaupal, immediacy of feedback, comprehensibility of message, frequency of contact, capability and availability of e-chaupal facilitators in attending to their problem. Similarly, in this study, farmers extended their appreciation to the AgriCare Nepal Pvt. Ltd. and support of USAID Kishan Project, through which they were able to get support services of KCC. Almost all of them whole heartily suggested to continue this type of services and expansion of such portals in different regions of the country with frequent monitoring and visits by agriculturists.

CONCLUSIONS

From the study, it was clear that farmers' involvement in commercial farming, pest problems was the major one among the various problems, and involvement of the literate, male and middle age category farmers to take services from KCC was observed to be higher. The use of KCC is increasing to solve farmers' pest problems and KCC's recommended treatment has been effective to control pests. Therefore, strengthening and extension of such services in different regional area would cover large numbers of farmers and highly benefitted by the services of KCCs.

i. The symptoms of the disease in the farmer's field need to be clearly described to the KCC for proper diagnosis of their pest problems.
ii. The recommendation made by KCC has been quite effective and in line with Integrated Pest Management suggested to farmers for ecofriendly management of the pests.
iii. Study shows that respondents are highly satisfied by KCC services, so strengthening and expansion of its services could benefit huge mass of farmers, who are out of reach of KCC service at present and those seeking such services.
iv. KCC services are less in number but its effectiveness is good, therefore, it is imperative for other NGO/INGO and private sectors to establish such KCC and solve farmers' problems together.

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