"ONLY ONE EARTH"

"दिगो प्रकृतिमैत्री जीवनयापन : पृथ्वीको संरक्षण"

The Journal of
AGRICULTURE AND ENVIRONMENT

(This issue is published on the occasion of World Environment/Population Day-2022)

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EDITORIAL

The World Environment Day (June 5), UN Environment-led global event, takes place on June 5 every year and is celebrated all over the world involving all categories of people. "ONLY ONE EARTH" is the UNEP theme for World Environment Day 2022.

The day is being celebrated through several events and relevant environmental campaigns. Food Security and Food Technology Division in the Ministry of Agriculture and Livestock Development has been publishing **The Journal of Agriculture and Environment** to mark the World Environment Day every year. The division now has brought the journal's new issue, Vol.23, in the hand of readers. This volume essentially includes technical research and review articles, and has major coverage of agricultural biodiversity, agricultural finance, crops and livestock production technology, diseases and pest management, agricultural policies and programs. The Editor-in-Chief acknowledges the valuable contributions from authors, reviewers, editors, and the editorial management team, and hopes that the readers find the issue informative and knowledgeable. The Editorial Board will be pleased to receive valuable suggestions and feed backs to improve our forthcoming issues.

Editor-in-Chief

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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 editor. Guidelines to authors on preparation and submission of manuscript 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 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.

For a newspaper: Sunuwar, D.K., 2008. Ecosan toilets bring multiple benefit. The Kathmandu Post, Vol. XVI (167), Aug 3, 2008:p.3(col.3).

For thesis/dissertation: Pokhrel, D. M., 2005. Citrus marketing systemin 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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DETERMINANTS OF FARMERS' PARTICIPATION IN BANANA INSURANCE IN CHITWAN DISTRICT, NEPAL

S. Timilsina[1*], M. Khanal[2], R. Pradhan[3], A. Bhattarai[1] and M. Sapkota[3]

ABSTRACT

This study was conducted to identify the factors affecting the adoption of banana insurance in Chitwan district of Nepal. A total of 160 samples (80 insurers and 80 non-insurers of banana producers) were selected randomly to collect primary data. Primary data were collected by conducting household survey using personal interview method in the month of September 2019. The logit model was used to identify the factors affecting the adoption of banana insurance policy among farmers. The result showed that the explanatory variables, area under banana cultivation, membership to cooperatives, and awareness about the agriculture insurance, perception of farmer about the necessity of crop insurance, agriculture extension services, and age of banana orchard were significantly contributing to the adoption of banana insurance policy. It also revealed that organization of awareness program, mobilization of groups and cooperatives were the important tools to promote banana insurance program. The findings would be helpful to make the insurance program more effective and hence increase the adoption of insurance policy and ultimately benefit farmers by enhancing their ability to manage risks in agriculture.

Key words: Adoption, banana, insurance policy, logit model, risk

INTRODUCTION

Most of the Nepalese industries are agriculture-based accounting for about 34%of annual export (Department of Customs, 2019). Expansion of agriculture sector is the milestone for the overall economic growth of the country (MoF, 2018). Farming is a risky business by definition.Several abiotic stresses, such as hailstorm, flood, drought and biotic stresses, such as diseases and pests results into instable income from agricultural activities (Nnadi *et al.*, 2013; Dhakal, 2019).There are other several factors such as environmental risks, market related risks, logistical and infrastructure risks, management and operational risks, policy and institutional risks, and political risk (Jaffee *et al.*, 2008) which are basic elements that affect performance of agricultural sector and are beyond the control of farmers.In Nepal, impact of weather

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related risks is remarkable as agricultural systems heavily rely on natural weather conditions (GoN, 2014). As majority of agriculture land (75 %) is lacking year-round irrigation, agricultural production is largely based on the monsoon rainfall (MoF, 2018). Management of losses due to such risk and uncertainties is crucial for establishing trust among farmers and motivating farmers to adopt modern agricultural technologies that can shift agricultural production through higher productivity (Dhakal, 2019).

The most extensively adopted risk management strategy in agriculture is insurance.It is an equitable transfer of a risk from one entity to another in exchange for a premium: a guaranteed and quantified small loss to avoid a huge and potential devastating loss (Iturrioz, 2009). It is a financial indemnity that compensates the monetary loss (Mahul and Stutley, 2010).The adoption of agriculture insurance policy assist individuals to achieve economic growth even after a disaster by compensating the individuals for the financial losses incurred (Warner *et al.*, 2013). It serves as security for banks by increasing the confidence for the banks to provide loan (Nnadi *et al.*, 2013). Melecky and Raddatz (2011) found that countries having high insurance penetration rate can maintain a positive GDP trend even after a devastating event.

Agriculture insurance was formally initiated in Nepal on 14 January, 2013 after the implementation of Crop and Livestock Insurance Directives, 2013(Insurance Board, 2017). Government of Nepal introduced fifty percent subsidy on insurance premium in the same year which was further increased to seventy-five percent in the year 2014. Agriculture insurance has been prioritized by the national government in its national policies, plans, programs, and budgets (MoALD, 2019; Insurance Board, 2017; MoAD, 2015). Due to this facilitation by government, number of farmers adopting agriculture insurance policy is increasing with time. However, the volume of adoption of insurance policy is not satisfactory in comparison to our neighboring countries. Crops covered less than five percent of agriculture insurance based on sum insured and less than three percent based on the number of insurance policies in the year 2020/21(Insurance Board, 2021).

Banana is one of the important summer fruits of Nepal contributing 0.85% to Agriculture Gross Domestic Product (AGDP) (MOALD, 2021). The area, production and productivity of Banana was 16,699 hectare (ha), 254,161 metric tonnes (mt) and 15.22 mt/ha respectively in 2019 in Nepal (MOALD, 2021).Morang, Jhapa, Saptari, Chitwan and Kailali were top 5 banana growing districts of Nepal based on area coverage in the year 2019/20. Banana was cultivated in 2,329 ha land and producing 28193 mt of fresh banana in the fiscal year 2019/20 in Chitwan district (MoALD, 2021).

Banana crop is highly susceptibleto weather related hazards like wind and hail due to its succulent nature(Ghimire *et al.*, 2016). Strong wind in 2005destroyed around 400 ha banana area in Nawalparasi district and western terai (World Bank, 2009). Similarly, strong winds accompanied by hailstones damaged 88 ha of banana that worthed millions of rupees in Chitwan district in 2018 (Rimal, 2018). Apart from this, banana faces biological risks such as insects and diseases, and market related risks, such as price fluctuation (Ghimire *et al.*, 2016). Encouraging farmers to adopt agriculture insurance policy is crucial for protecting farmers from economic losses due to such catastrophic events (Warner *et al.*, 2013). The objective of this study was to identify the factors affecting the adoption of banana insurance policy in Chitwan district, Nepal.

METHODOLOGY

STUDY AREA AND DATA COLLECTION

Among other crops cultivated in Nepal banana had highest rate of insurance adoption in 2018/19. The number of insurance adopter were higher in Chitwan district of Nepal (Department of Agriculture, 2018). Hence, Chitwan district was purposively selected for this study and farmers involved in banana production were randomly selected to collect primary data. This study utilized both primary and secondary data. Each selected household were the key source of the primary data. The primary data obtained from semi-structured interview schedule, Key Informant Interview (KII) were used to triangulate the household data. Since the number of banana farmers were found higher in Kalika and Ratnanagar Municipality of Chitwan district, these two municipalities were purposively selected to collect primary data and household survey was carried out in the month of September 2019.The total of 80 households adopting the banana insurance policy and same number of households not adopting the banana insurance policy were selected for the collection of primary data.

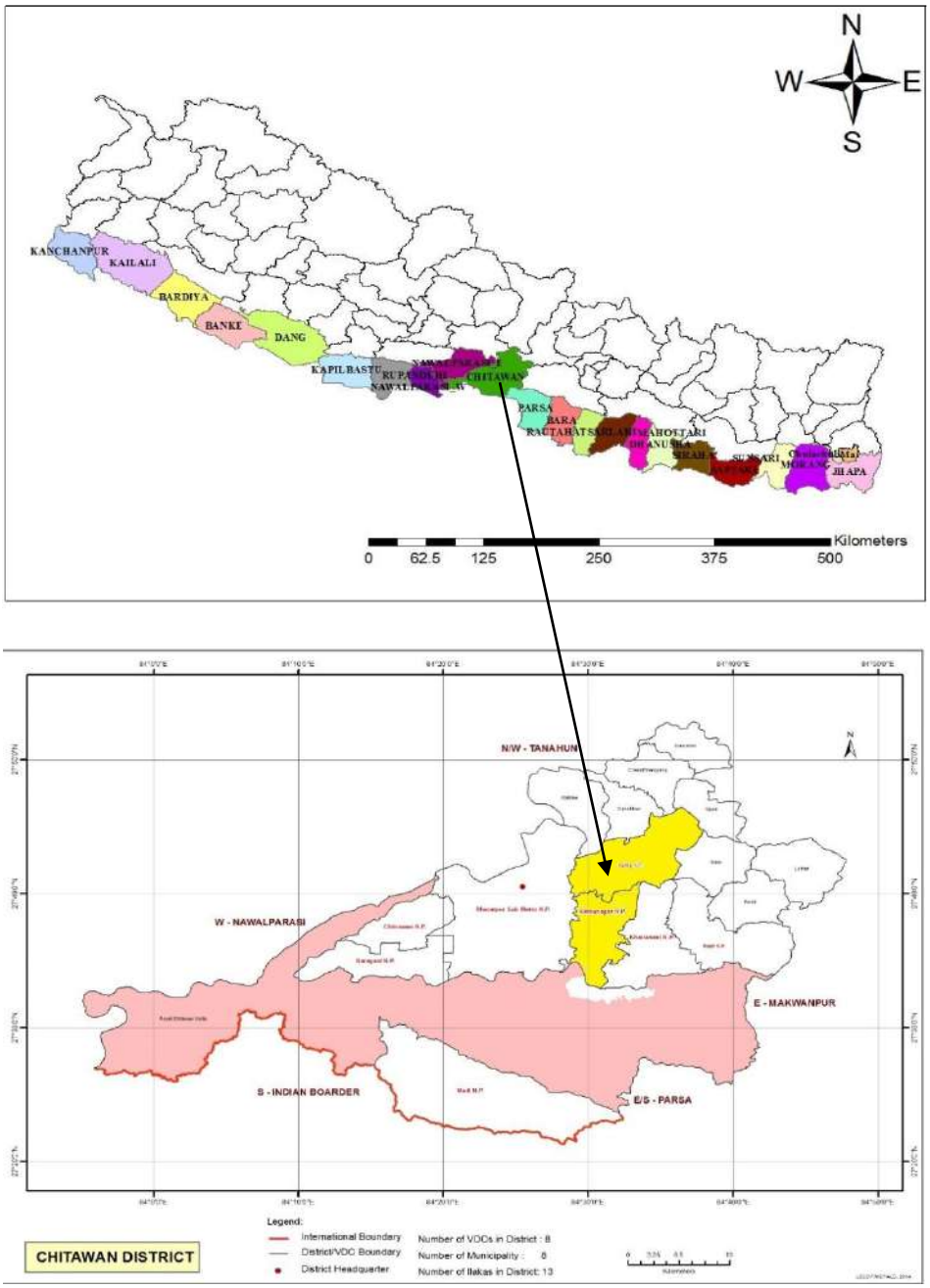

Figure 1. Figure showing map of Nepal and Chitwan District. The green shaded area in the map of Nepal is Chitwan district and yellow shaded area in the map of Chitwan district is study site for this study.

DATA ANALYSIS

Both qualitative and quantitative data were obtained from the field survey. The primary data collected were entered to Microsoft excel 2010 and descriptive analysis was done using Statistical packages for Social Sciences (SPSS) version 15 and regression model analysis was done using Stata software version 12.The factors affecting the adoption of banana insurance policy was analyzed using Logit regression model. .

ANALYTICAL MODEL

The logit model was used to evaluate the extent to which different independent variables affected the adoption of banana insurance policy decision (Greene, 2000). There were many studies where logit regression model had been used to assess the factors affecting the adoption. The study carried out by Sujarwo and Rukmi (2018); Branstrand and Wester (2014); Kwadzo, Kuwornu and Amadu (2013) also used logit regression model to assess the factors affecting the adoption of crop insurance policy.The dependent variable is binary response where,Y= 1 for adopting an insurance policy, and Y=0 for not adopting an insurance policy.

$P(Y=1) = f(b' X)$ --------- equation 1

Where,

P = the probability

Y = Adoption of insurance policy = 1, otherwise zero.

b = logit coefficient $(b_1 \ldots\ldots b_n)$

X = Explanatory variables $(X_1 \ldots\ldots X_n)$

The probability for Y = 0 according to equation 1 is

$P(Y=0) = 1 - f(b' X)$

The likelihood of farmers adopting the insurance is a non-linear function of regressors.

$P(Y=1) = (X_i)$

Model Specification

$$Pr(Y=1) = f(b_o + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10} + b_{11}X_{11} + b_{12}X_{12} + b_{13}X_{13})$$

$b_1, b_2 \ldots b_{13}$régressions coefficients, b_0= intercept, ε= error term, i=n=160

Table 1. Description of the dependent and explanatory variables used in Logit model

Variables	Type of variable	Description	Expected sign
Dependent	Binary	Adoption of crop insurance policy (Adoption=1, Otherwise 0)	
Gender of Household head HHH(X_1)	Binary	(Male =1, Otherwise 0)	(±)
Schooling HHH (X_2)	Continuous	Years of schoolingof HHH	(±)
Experience HHH (X_3)	Continuous	Banana farming experience of HHH (years)	(±)
Irrigation (X_4)	Binary	Irrigation facility (Yes=1, Otherwise 0)	(±)
Area (X_5)	Continuous	Natural log transformation of area under banana cultivation	(+)
Age of banana orchard (X_6)	Continuous	age of banana orchard	(+)
Extension (X_7)	Binary	Farmer received Extension Services (Yes=1, Otherwise 0)	(+)
Diversification (X_8)	Binary	Diversified source of income (Yes=1, Otherwise 0)	(±)
Membership (X_9)	Binary	Membership inagriculture cooperatives (Yes=1, Otherwise 0)	(+)
Awareness year (X_{10})	Continuous	Number of years the farmer has been exposed or aware about insurance	(+)
Perception (X_{11})	Binary	Perception of farmer on the importance of insurance service for agriculture(Very necessary =1, Otherwise 0)	(+)
Subsidy knowledge (X_{12})	Binary	Understandingabout subsidy in insurance premium (Yes=1, Otherwise 0)	(+)
Credit (X_{13})	Binary	Credit access (Yes=1, Otherwise 0)	(±)

RESULTS AND DISCUSSIONS

SOCIO-ECONOMIC AND DEMOGRAPHIC CHARACTERISTICS

The columns 2 and 3 of table 2 presents the socioeconomic and demographic characteristics of banana insurance policy adopters and non-adopters respectively. Columns 4 and 5 shows the differences among the two categories of farmers. The differences are presented through t-test for continuous variables and chi-square test

for categorical variables.Chi-square test revealed that extension services, membership in cooperatives, perception on importance of insurance, awareness about the government subsidy in insurance premium and accessibility to credit from formal sources, were determining factors for adoption of banana insurance policy decision. The results were significant at 1% level. However, no significant difference in the diversification of farm was observed between adopters and non -adopters.

The findings of t-test shows that years of schooling, experience of banana farming, area of banana cultivated, production of banana, income from banana, age of banana orchard and number of years famers are aware about insurance were different between adopters and non-adopters with significant result at 1% level of confidence. However, area of irrigated land was similar among both groups.

Table 2. Socio-economic and Demographic characteristics of the sampled households

Variables	Insurance Adoption		Test Statistics	
	Yes (n=80)	No (n=80)	t-test	Chi-square
Gender of HHH (male = 1)	73 (91.3)	65 (81.3)		3.373*
Year of schooling)	10.7	8.23	4.417***	
Experience (in year)	8.6	5.25	4.56***	
Area (ha)	3.49	0.91	4.595***	
Age of banana orchard	4.58	2.86	5.186***	
Awareness year	4.14	2.88	5.042***	
Extension received (Yes = 1)	48 (60)	23 (28.7)		27.16***
Membership (Yes =1)	73 (91.2)	52 (65)		16.128***
Perception (necessary = 1)	77 (96.2)	54 (81.8)		8.171***
Subsidy knowledge (Yes =1)	71 (88.8)	38 (47.5)		31.34***
Credit (Yes =1)	43 (53.8)	20 (25)		13.850***
Irrigation (Yes = 1)	3.30	0.88	4.199	
Diversification (Yes = 1)	55 (68.8)	62 (77.5)		1.558
Production (Mt)	88.89 (126.99)	23.92(45.41)	4.3***	
Income from banana (NPR 000')	1902.56 (2615.15)	566.00 (986.62)	4.28***	

Source: Field Survey, 2019 (Note: Figures in Parentheses indicate percent. *** and *indicates significant at 1 and 10% level of significance.)

FACTORS AFFECTING THE ADOPTION OF BANANA INSURANCE POLICY

The description of dependent and independent variables are given in table 1. The statistical analysis of factors affecting the adoption of crop insurance in banana was done using the logit model. The multi collinearity of the explanatory variables was checked by using VIF and there was no issue.The likelihood ratio chi-square)LR chi^2 (for the model was statistically significant at 1 %level of significance which revealed

that the model had good explanatory power .The log-likelihood indicates that the explanatory variables included in the model jointly explain the probability of farmers ' decision to purchase banana insurance policy.

The result of logit regression model is described below in table. The increase in banana area by 1%, the probability of adoption of banana insurance policy would increase by 19% keeping all other factor constant and was found statistically significant at 1% level of significance. The increase in area under banana cultivation means increasing investments on banana production and also increasing risks which attracts farmers towards purchase of insurance policy for the minimization loss incurred. The study conducted by Ntukamazina *et al*. (2017) in Sub-Sahara, Africa, also found positive relationship between farm size and adoption of insurance policy.The finding was also consisted with the study conducted bySihem (2019), Bharati *et al*. (2014) and Ali (2013) where they found positive and significant relationship between the farm size and adoption of insurance policy.

Similarly, the increase in the age of banana orchard by 1 year, the probability of adoption of banana insurance policy would increase by 7.4% and was found statistically significant at 5% level of significance. The more the age of banana orchard, the more risky is the farm. Ghimire *et al*. (2016) found that banana farmers were not interested to insure their newly established banana orchard due to belief that there would be minimum crop losses. The findings was also consisted with the study conducted by Goodwin, Vandeveer and Deal (2004).

The result revealed that farmers who had received extension services, the probability of adoption of banana insurance policy increases by 24% and was found statistically significant at 10% level of significance. Farmers get aware about the importance of insurance and they would be likely to adopt insurance policy.The study by Ellis (2017) in Ghana found the farmers who had received extension services, the probability of purchase of policy would increase by 61.1%. Ali (2013) also found positive and significant relation between access to extension service and willingness to participate in index-based crop insurance in Pakistan. The finding was also consisted with the study of Falola, Ayinde and Agboola (2013) conducted in Nigeria where they found the positive relationship between access to extension service and willingness to purchase insurance policy.

Similarly, membership in cooperatives, number of awareness year on insurance and perception of farmer about the importance of insurances were found positively and significantly affecting the adoption of banana insurance policy. The farmers who were

the members of cooperatives, the probability of adoption of banana insurance policy would increase by 21.6% and similarly increase in awareness year about insurance would increase the probability of adoption of banana insurance policy by 6.5%. The increase in farmer's perception about the importance of insurance would increase the probability of adoption of banana insurance policy by 23.5%. The rest of the other explanatory variables were found statistically non-significant.

Membership in a farmer cooperative organization provides opportunity to farmers to know more about modern farming technologies and new interventions. Therefore, the farmers engaged in cooperatives are expected to avail agriculture insurance more compared to those who were not engaged. Ashimwe (2016) also found that membership in farmer cooperatives has positive and significant relationship with the adoption of index-based crop insurance in Rwanda. In contrary, Masara and Dube (2017) found that the more the number of years of involvement of a household head in a farmer groups has significantly negative influence on the adoption of agricultural insurance among smallholder maize farmers in Goromonzi district of Zimbabwe. Similarly, Singh and Hlophe (2017), Masara and Dube (2017) found that adoption of agriculture insurance was positively related to awareness on insurance.Ashimwe (2016) also found a positive and significant relationship of the years of experience and the adoption of weather-index crop insurance in Rwanda.Similarly, the study of Yang *et al*. (2015) revealed the significant and positive influence on the level of farmers' awareness about agricultural insurance and the participation in agricultural insurance. The findings of the study conducted by Karthick and Mani (2013), Tamil Nadu, India revealed that awareness about the benefits of adopting insurance influenced the adoption of crop insurance as farmers realized that adopting crop insurance will minimize income loss occurred due to adverse weather events, pests and diseases.

Table 3. Factors determining the adoption of banana insurance policy using Logit model

Variables	Coefficients	Standard error	p-value	dy/dx	Standard error
Gender of HHH (male = 1)	0.109	0.688	0.874	0.027	0.171
Year of schooling of HHH	0.085	0.074	0.252	0.021	0.018
Experience in banana production (in year)	0.019	0.053	0.715	0.004	0.013
Area (ha)	0.763***	0.240	0.001	0.190	0.060

Variables	Coefficients	Standard error	p-value	dy/dx	Standard error
Age of banana orchard (in year)	0.299**	0.138	0.031	0.074	0.034
Extension service (Yes = 1)	0.980*	0.513	0.056	0.240	0.120
Membership in cooperatives (Yes = 1)	0.878*	0.514	0.088	0.216	0.122
Awareness year on insurance	0.260*	0.155	0.094	0.065	0.038
Perception of farmer about importance of insurance (Yes = 1)	0.972*	0.564	0.085	0.235	0.128
Knowledge on subsidy (Yes = 1)	0.798	0.624	0.201	0.195	0.147
Credit access (Yes = 1)	0.299	0.510	0.557	0.074	0.126
Irrigation facility (Yes = 1)	0.507	0.774	0.512	0.125	0.185
Diversification on income (Yes = 1)	-0.384	0.644	0.551	-0.096	0.158
Constant	-5.380	1.510	0.000		
Number of Observations	160				
Log Likelihood	-59.351				
LR chi^2 (15)	103.10***				
Prob>Chi^2	0.0001				
Pseudo R^2	0.4648				

Source: Field Survey (2019)

Notes: ***, ** and * indicate significant at 1, 5and 10% levels, respectively.

DETERMINATION OF GOODNESS OF FIT

A goodness-of-fit test was conducted to determine how well the model fits the data. The Hosmer-Lemeshow test compares the predicted values in groups with the observed values (Hosmer D.W. and Lemeshow S, 1989). The p-value in the Hosmer-Lemeshow test being lower than 0.05 indicates that the model does not fit the data. Here, Hosmer – Lemeshow value was 0.2548 which indicates that the model fits the data well.

CONCLUSIONS

The study was conducted to assess factors affecting the adoption of banana insurance policy in Chitwan district of Nepal.The research problem addressed in this study was to determine the reasons behind the low adoption of agriculture insurance and make recommendations for improvements. The findings revealed that socio-economic and demographic factors such as area under banana cultivation, membership to cooperatives, awareness about the insurance scheme, perception about the importance of crop insurance, access to extension services, and (age of banana orchard had significant effect on the adoption of banana insurance policy. It is necessary to raise awareness about agriculture insurance and their importance through government agencies, I/NGOs, insurance companies, and farmers' organizations.Since subsidy in agriculture insurance premiums is necessary for the rapid growth of insurance, the government should continue to provide the subsidy. The different concerned stakeholders should increase their extension services and this should be regularly provided to the farmers.

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ASSESSMENT OF THE SPATIAL DISTRIBUTION AND MAPPING SOIL PHYSICO-CHEMICAL PROPERTIES OF NALGAD MUNICIPALITY, JAJARKOT, NEPAL

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ABSTRACT

A detailed soil inventory study using Global Positioning System (GPS) and Geographical Information System (GIS) was conducted in Nalgad Municipality of Jajarkot, Nepal in 2019. A preliminary reconnaissance survey during pre-field activities and detail field work was carried out to study the soil type and physico-chemical properties based on the soil pit. A total of 51 soil pits were taken in the field representing varied micro topography. Soil Sample pits covering all the units were dug based on the interpreted soil map, topographical map, ZY-3 Satellite imagery for determination of soil profile. Soil classification of the area was done based on the USDA soil taxonomy and the dominant soil orders found in the region were Entisols (15.13 %) and Inceptisols (83.60%). A total of 51 geo-referenced composite soil samples from a depth of 0-20 cm was collected from each pit and analyzed in laboratory for texture, soil pH, soil organic matter, total nitrogen, available phosphorus and exchangeable potassium. Majority of the soil are loam and loamy sand type. There is very low to high level of organic matter present in the study area with more proportion of land under high range of organic matter (64.98%). Total Nitrogen content in soil of the study area ranges from very low to very high level with high level of Nitrogen (65.51%) in major proportion. Low to very high level of available phosphorous content was found in the study area with the dominance of very high level of phosphorous (71.40%). Exchangeable Potassium level in the study area is very high to low. Around 42% land have very high level of potassium. From the soil test result, major nutrients status in soil were found to be good but integrated land management practices should be encouraged for improving land productivity. The generated soil maps may be helpful to stakeholders for planning, monitoring and evaluating the soil status for effective agricultural production.

Keywords: GIS, Nalgad municipality, soil, soil map

INTRODUCTION

Soil is everything more than life for us, as we are totally dependent on agriculture for our livelihood from time immemorial (Adhikari and Hartemink, 2016). Whatever the technological advances achieved, soil will always be necessary for humans to grow most of the food, fodder and fiber they need (Chen *et al.*, 2022). The growing population and decreasing soil productivity is a problem that has long gone unsolved. In order to make optimum use of our limited soil resources, we need detailed

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information about their characteristics, types, and distribution on landscape. The use of high spatial resolution maps and digital techniques to map soil properties is of particular importance. Describing the spatial variability of soil across a field has been difficult until new technologies such as Global Positioning Systems (GPS) and Geographic Information Systems (GIS) were introduced (Reddy *et al*., 2018). The use of GIS and GPS for land use planning and soil mapping is popular and gaining acceptance worldwide which are adopted for better management of land and other resources for sustainable crop production (Palaniswami *et al*., 2011). In agriculture, GPS and GIS technologies have been based on the geo-statistical analysis and several studies have been conducted to characterize the spatial variability of different soil properties (Hwang *et al*., 2007; Weindorf and Zhu 2010; Liu *et al*., 2013).

Systematic land use planning is an effective tool to formulize national level land use policy for utilization of land according to its productive capacity and usefulness (GIZ, 2011). GIS-based soil maps are useful for developing solutions to resource management issues such as land management, soil erosion, soil degradation, fertility evaluation and urban planning (Tomlinson *et al*., 1987). GIS generated soil maps may serve as a decision support tool for nutrient management (Iftikar *et al*., 2010) and it also helps to determine plant nutrient availability and distribution and the pattern of nutrient depletion in the project area. Among the different geo-statistical methods, ordinary kriging is widely used to map the spatial variation of soil fertility because it provides a higher level of prediction accuracy (Song *et al*., 2013). The main objective of the study was to prepare a scientific and comprehensive soil map of Nalgad Municipality of Jajarkot District, a part of Karnali Province of federal Nepal and characterize the spatial distribution of soil physico-chemical properties such as soil type, texture, pH, organic matter and major nutrients.

MATERIALS AND METHODS

STUDY AREA

Nalgad Municipality of Jajarkot District, a part of Karnali Province of federal Nepal and geographically lies in high hill and Mahabharata range. The spatial area of the Municipality comprised by covering the watershed areas of Nalgad River and Bheri River as the confluence area of the Nalgad into Bheri River and named as Nalgad municipality.

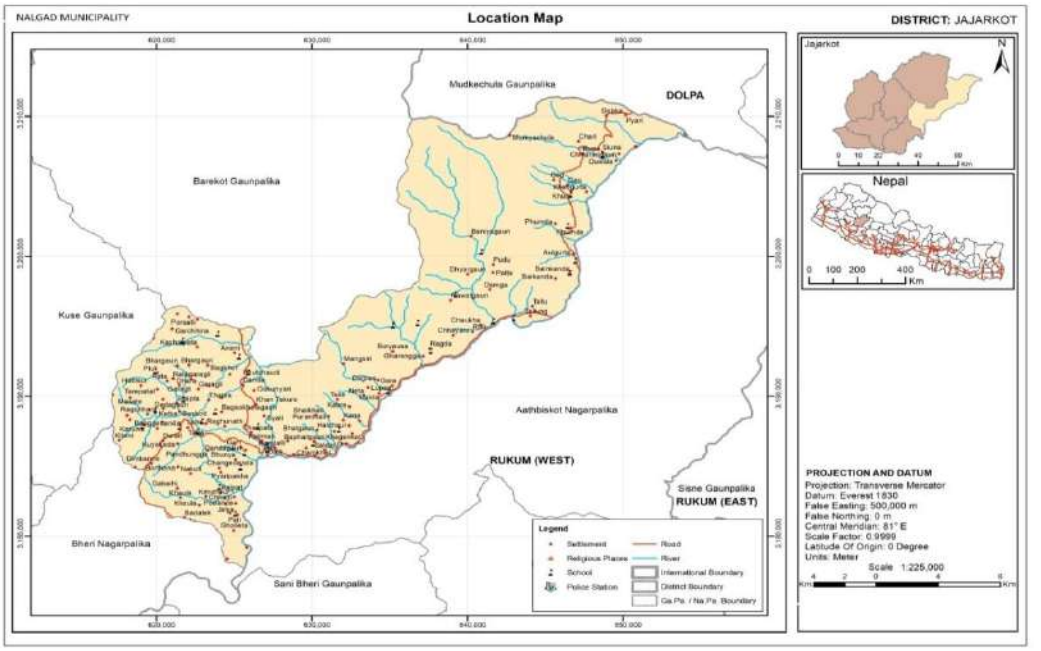

Figure 1: Location Map of Nalgad Municipality, Jajarkot

The municipality extends from 82˚12'4.941" east to 82˚34'54210" eastern longitudes and 28˚ 42'47.759" north to 29˚01'2.792" northern having an area of 387.44 square km with 43.56 km north-south length and 17.15 km east-west width (Figure 1). Its elevation ranges from 760 to 5212 meter above sea level.

DETERMINATION OF SAMPLING POINTS

The digital LRMP maps, land system, land capability and land use at the scale of 1:50,000 and geological Map scale at 1:125000 together with Municipality map and Topographic - thematic layers at 1: 25,000 and ZY-3 Satellite imagery provided by National Land Use Project/ Survey Department and available reports were reviewed in connection with preparation of soil map prior to the field survey. The soil mapping units were demarcated based on the land units that also identified capturing the local topography variation. The description of soil mapping unit and the symbol was formed with the integration of land system, landform, land type and geological map and land use/land cover. Soil mapping units derived from Land units were formed and overlaid on Standard False Color Composite (RGB: 432) of the project area at the scale of 1:10000. Altogether 51 soil pits and their location were obtained for the soil pits collection where detailed soil profile was studied. The spatial distribution of those soil pits are shown in Figure 2.

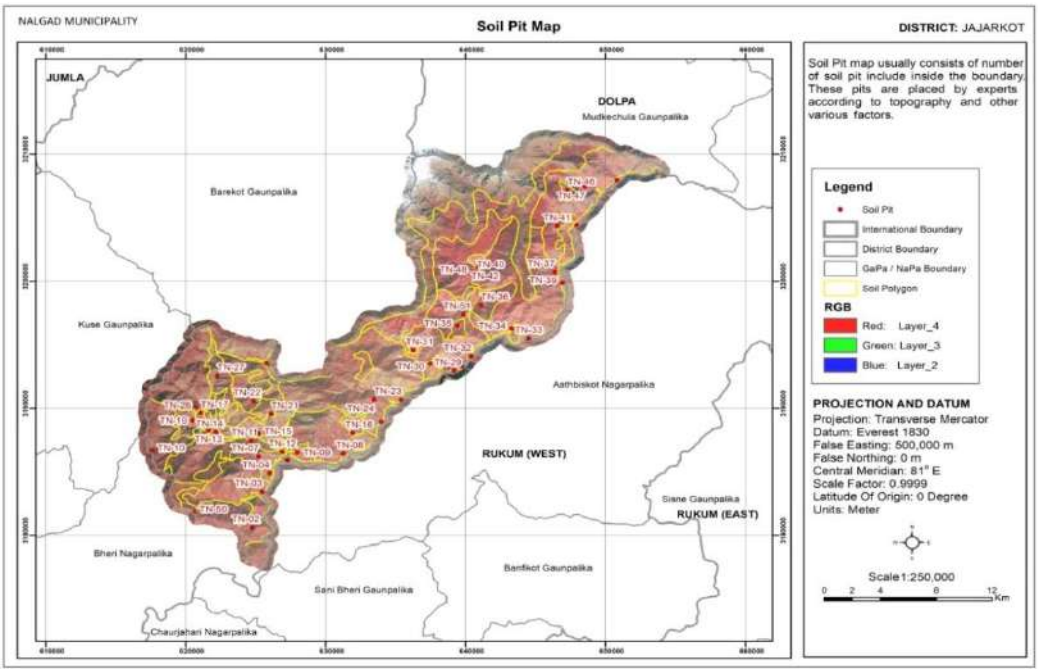

Figure 2. Sample soil pit location map of Nalgad Municipality

A preliminary reconnaissance survey was carried out during the pre –field activities to get the insight of ground situation of project area regarding the association of landform and soil. Soil Sample pits covering all the units were dug based on the interpreted soil map, topographical map, and ZY-3 satellite imagery for determination of soil profile. The digging of soil pits was carried out from 5th September 2019 to 20th September 2019 at the concerned Municipality. These sample pits were studied in the field for soil mapping and soil profile observation. Each soil profile (pedon) description is carried out as per the Standard Soil Profile Description Form provided from Survey Department, Ministry of Land Management, Co-operatives and Poverty Alleviation, Nepal. Soil of each horizon was described following USDA guidelines.

SOIL SAMPLING AND ANALYSIS

Composite soil samples from 20 cm depth of top layer were collected from area around each pit and the samples were analyzed at Soil and Fertilizer Testing Laboratory, Hetauda to examine the chemical properties (N, P, K, OM, pH) of soil including soil texture. Top layer or epi-pedon particularly first horizon was examined in the laboratory for the purpose of soil fertility assessment whereas sub-surface or endopedon was assessed for the soil classification purpose. The soil samples collected were preserved in airtight plastic bags, dried in shade and powdered to pass through

2 mm size sieve that were used for examination of physical and chemical analysis in the laboratory using the specific methods

Table1. Methods adopted for soil analysis in laboratory

Soil Sample Tests	Analysis Method
Texture	Hydrometer method (Gee and Bauder, 1986)
pH	Beckman electrode pH meter (Cottenie *et. al.*, 1982)
Organic Matter content	Walkley and Black Method (Walkley and Black, 1934)
Available Phosphorous(P_2O_5)	Modified Olsen sodium bicarbonate method (Olsen et. al.,1954) extraction and detected in spectrophotometer in 560 nm
Available Potassium(K_2O)	1 N neutral ammonium acetate 5 min shaking and filtered through Whatman No 42 filter paper and detected through flame ignition (Pratt, 1965)
Total Nitrogen(N)	Kjeldahl method (Bremner and Mulvany, 1982)

SOIL MAPPING

Soil association as the universally accepted for soil mapping was adopted in order to correlate the soil pit and soil mapping units. The rating (very low, low, medium, high and very high) of determined values were based on National Soil Science Research Centre, Khumaltar, Nepal (table 2). Based on morphological and chemical analysis data soils are classified according to Soil Taxonomy (USDA, 2010). After completing the field study, the soil pits location was transferred into base map and image through GIS data analysis. Arc Map 10.1 with geo-statistical analyst extension of Arc GIS software was used to prepare spatial distribution map of soil parameters at 1:25000 scale, while interpolation method employed was ordinary kriging with stable semi-variogram. Descriptive statistics of soil properties, including mean, standard deviation, coefficient of variation, minimum and maximum were calculated using STAR software.

Table 2. Rating for different soil chemical parameters given by NSSRC for hill region of Nepal

Rating	Organic Matter (%)	Total Nitrogen (%)	Available P_2O_5 (Kg/ha)	Available K_2O (Kg/ha)
Very Low	<1.0	<0.05	<10	<55
Low	1-2.5	0.05-0.1	10-30	55-110
Medium	2.5-5.0	0.1-0.2	30-55	110-280
High	5-10	0.2-0.4	55-110	280-500
Very High	>10	>0.4	>110	>500

Range for pH: Very strongly acidic= >5.0; strongly acidic= 5.0-5.5; moderately acidic= 5.5-6.0; slightly acidic= 6.0-6.5; Neutral= 6.5-7.5; slightly alkaline= 7.5-8.5; moderately alkaline= 8.5-9.0; strongly alkaline=>9.0

RESULTS AND DISCUSSIONS

SOIL TYPES

Soils of Nalgad Municipality of Jajarkot district are classified based on the information of soil derived from soil pits and soil mapping unit level according to the USDA Soil Taxonomy. The soils are grouped according to Soil Orders, Sub-Orders, Great Groups, and Sub-Groups. Table 3 and Figure 3 present Soil Taxonomy classification for the soils of Nalgad Municipality.

Table 3. Soil Taxonomy Classification of Nalgad Municipality

SN	Soil Order	Sub order	Great Group	Sub Great Group	Area Ha	Percent (%)
1	Entisols	Orthents	Cryorthents	Lithic Cryorthents	3637.43	9.40
			Ustorthents	Lithic Ustorthents	2217.52	5.73
2	Inceptisols	Ustepts	Dystrustepts	Lithic Dystrustepts	14829.14	38.32
				Typic Dystrustepts	1019.80	2.64
			Haplustepts	Lithic Haplustepts	5277.39	13.64
			Humustepts	Lithic Humustepts	10466.31	27.05
				Typic Humustepts	759.63	1.96
3	Waterbody				489.75	1.27
Total					38696.96	100.00

In Nalgad Municipality, two major orders of soil were found viz. Entisols and Inceptisols. The majority of the soil is occupied by Inceptisols followed by Entisols. Lithic Dystrustepts occupied the largest area (38.32%) followed by Lithic Humustepts, Lithic Haplustepts, Lithic cryoorthents, Lithic Ustorthents, typic Dystrustepts and typic Humulstepts. In total Inceptisols occupied 83.60% area and Entisols occupied 15.13% area. The details of the area coverage by individual soil group was presented in table 3. The distribution of different soil types is well depicted in figure 3.

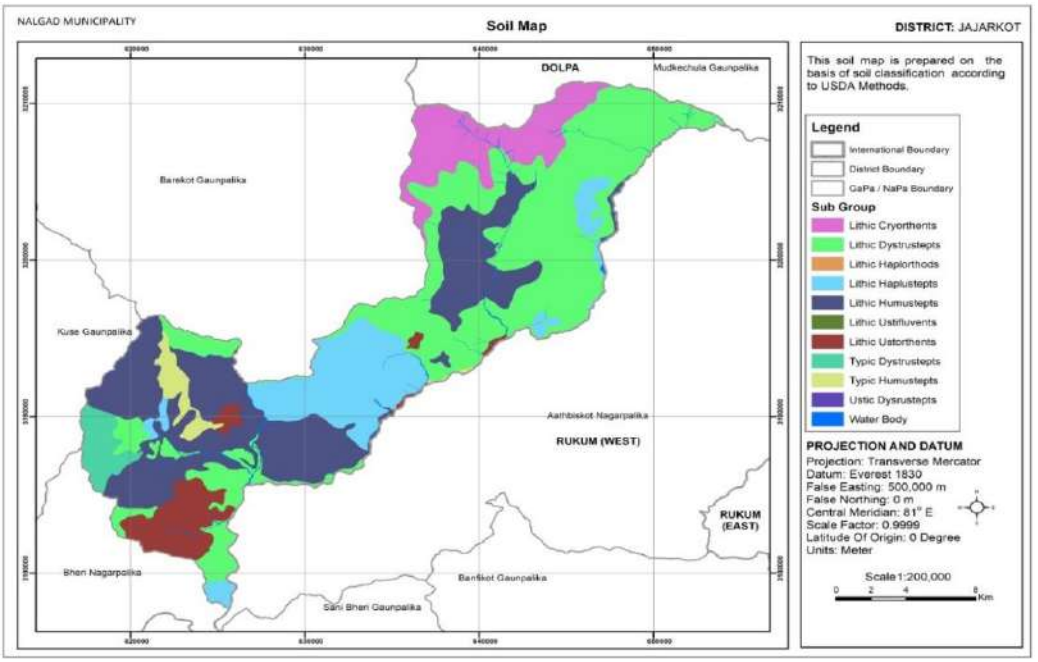

Figure 3. Soil map of Nalgad Municipality, Jajarkot, Nepal

Soil Order Inceptisols are extensively found in the Nalgad municipality having deep with well-developed properties of A and B horizons. In this order Haplustepts, Dystrustepts and Humustepts Great Groups are found in our study area of Nalgad Municipality.

Soil order Entisols found in the study area typically have little or no development of soil horizons and these soils are characterized not by the kinds of horizons that have formed but rather by their minimal degree of soil development. In particular areas, Entisols occurring more stable landscape positions. In these areas, the soils consist mostly of quartz or other minerals that are resistant to the weathering needed to form soil horizons or the soil-forming processes are hindered by extreme environmental conditions.

PHYSICAL AND CHEMICAL PROPERTIES OF THE SOIL

The results of soil analysis were presented in the table 3 and figure 4 to 9 for better understanding of the soil parameters that were investigated in the laboratory. The coefficient of variation (CV) ranged from 10.05 % (in pH) to 84.14 % (in K2O). The range of CV for the soil sampling locations suggested different degrees of heterogeneity among the properties studied. Majority of the soil are loam (51.71 %) and loamy sand type (17.44%). The site inhabiting loam texture is good for cultivation

various kinds of crops and fruits, while in silty loam, clay and clay loam site care should be taken for tillage and water management.

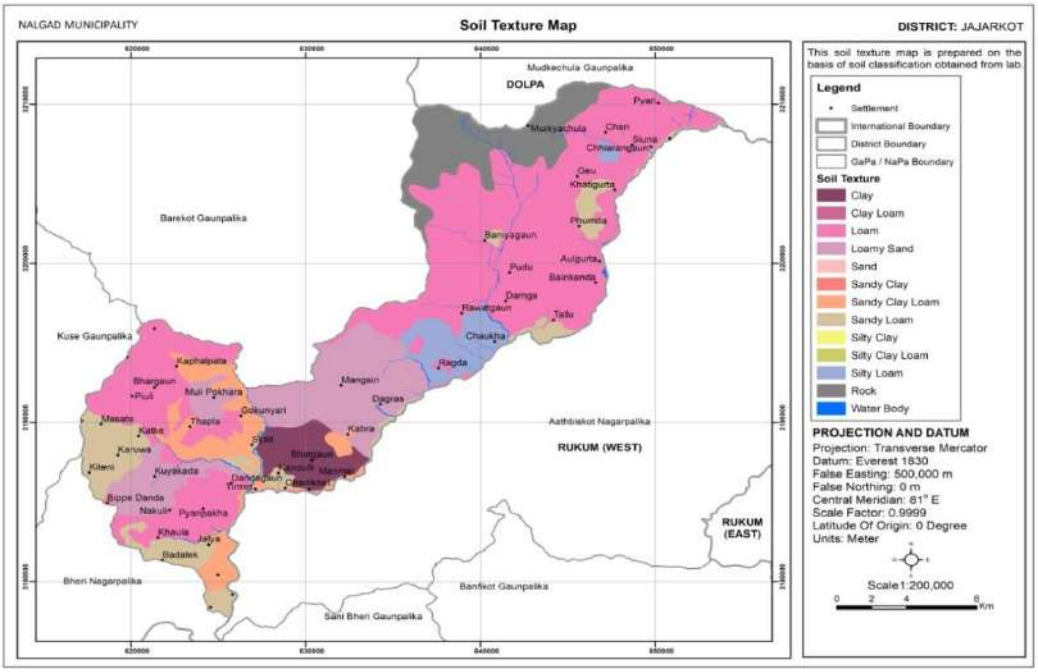

Figure 4. Soil texture map of Nalgad Municipality

The distribution of soil pH varied from highly acidic to moderately alkaline but most of the soils are neutral (45.01 %).The pH is an excellent indicator for determining chemical nature of the soil (Shalini *et al.*, 2003). The determined pH is suitable for most of the crops and fruits while special care should be taken in the acidic pH inhabiting sites.

Table3. Summary statistical overview for soil chemical properties of Nalgad Municipality (N = 51)

Soil Parameter	Mean	Standard deviation (SD)	coefficient of variation (CV)	Minimum	Maximum
pH	7.1	0.72	10.05	4.45	8.4
Organic matter (%)	4.45	1.88	42.19	0.33	6.45
Total Nitrogen (N %)	0.25	0.12	49.62	0.03	0.47
Available P_2O_5 (Kg/ha)	229.74	181.18	78.86	18.91	680.10
Available K_2O (Kg/ha)	375.92	316.46	84.14	87.60	1503.6

There is very low to high level of organic matter present in the study area with mean value of 4.45 % and more proportion of land (64.98 %) under high range of organic matter. Organic matter plays important role for improving various physical, chemical

and biological properties (Hoyle *et al.*, 2011). Therefore, different organic matter improving program (adding compost, crop residue retention etc.) is suggested regularly for maintaining organic matter in long-term. Total Nitrogen content in the study area ranges from very low to very high level with high level of Nitrogen (65.51%) in major proportion followed by medium level of nitrogen (13.01%) of the area. Very low to very high level of available phosphorous content was found in the study area with the dominance of very high level of phosphorous (71.40%) followed by high (13.16 %) and low (1.56%) level of phosphorus. Available potassium level in the study area is very high to low. Around 41.71% land have very high level of potassium, 16.28% land have high level, 27.62% have medium level of potassium and 3.72% have low level of potassium in Nalgad municipality.

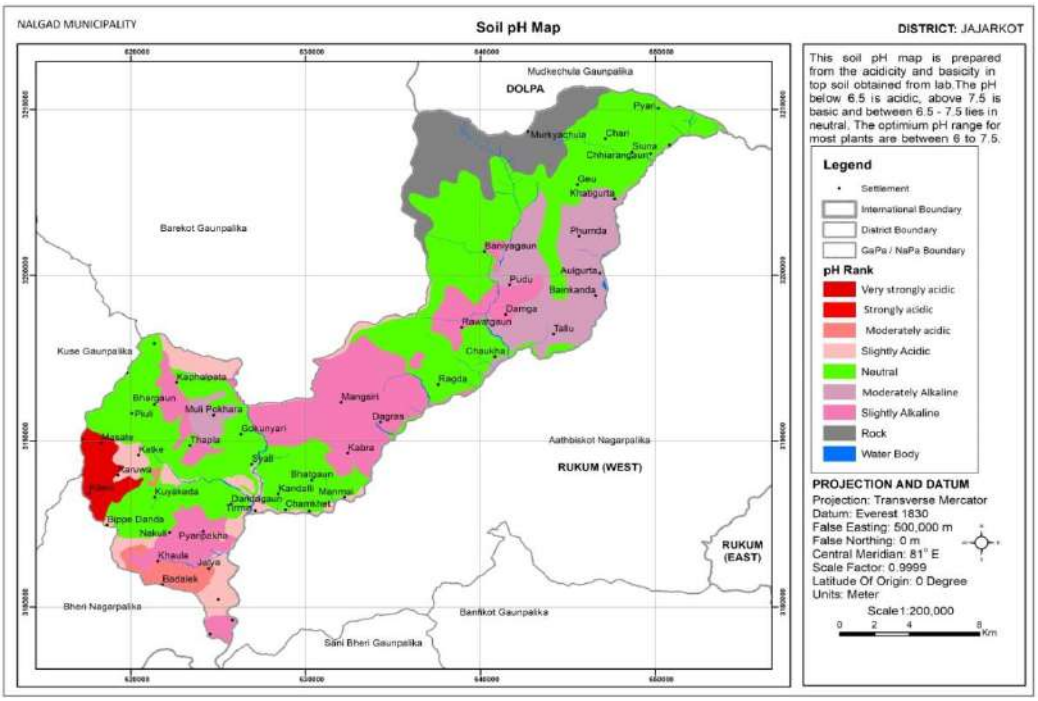

Figure 5. Soil pH map of Nalgad Municipality

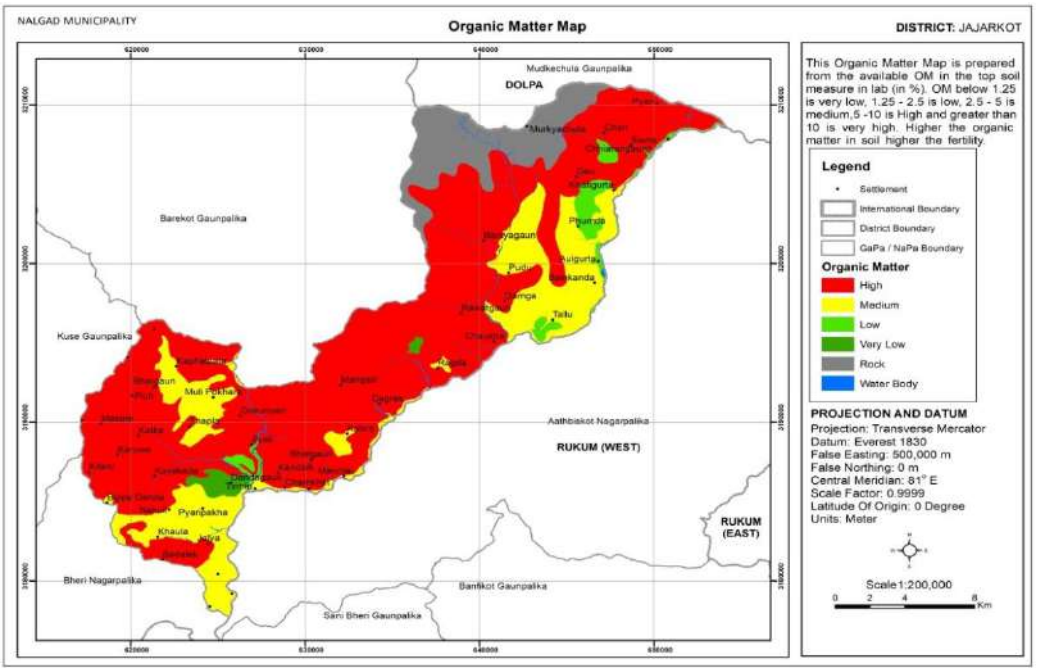

Figure 6. Soil organic matter map of Nalgad Municipality

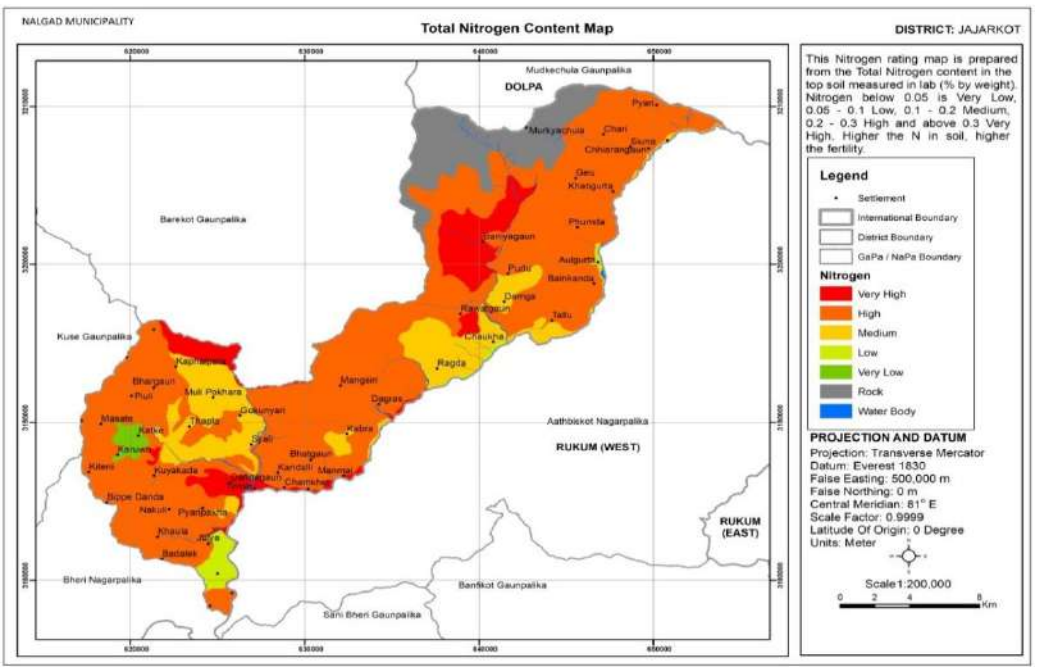

Figure 7. Nitrogen Map of Nalgad Municipality

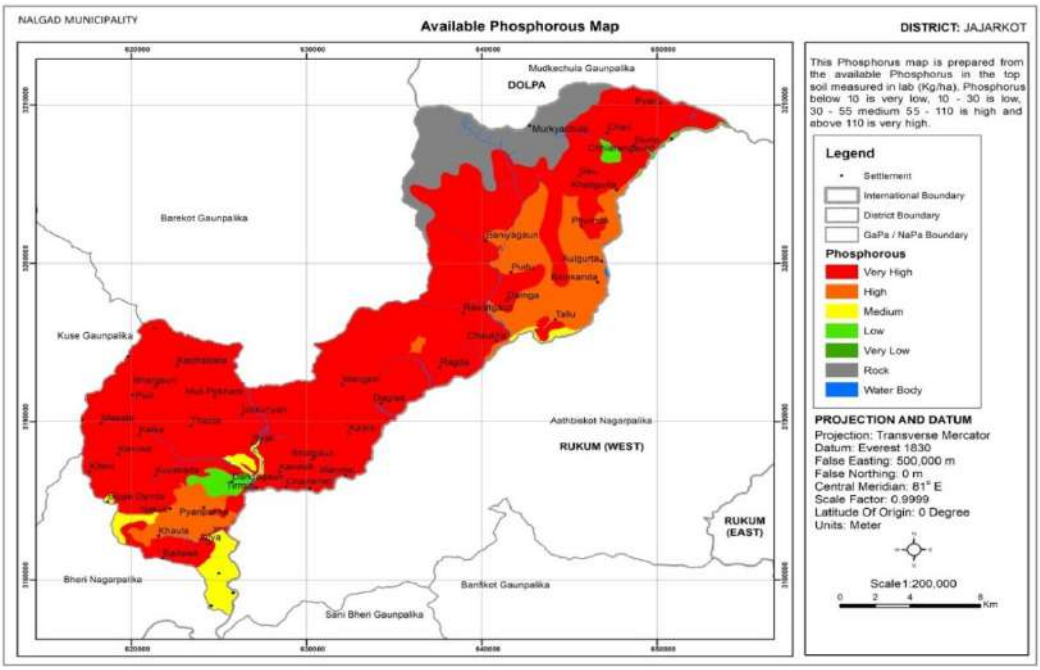

Figure 8. Phosphorous Map of Nalgad Municipality

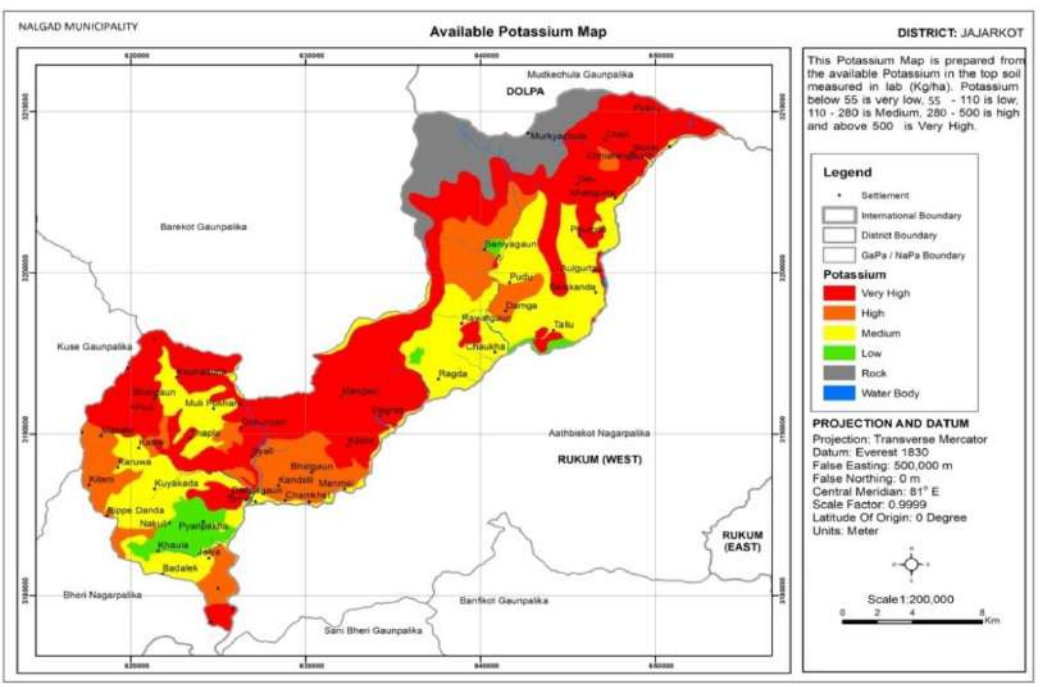

Figure 9. Potassium Map of Nalgad Municipality

Looking towards the spatial distribution of different soil nutrients, nitrogen content in soil is not sufficient which further triggered by the prevalence of nitrogen leaching, soil erosion and poor mineralization of organic matters. Phosphorus and potassium content in soil are in medium to high level. Organic matter in the soil ranges from low to high and majority of soil pH varies from medium acidic to neutral. The area having very low, low, medium and high status of major nutrients, 120 %, 100 %, 75% and 50% respectively of recommended dose of fertilizers should be recommended for adequate supply of nutrients for crops and no need of any fertilizers to those area having very high status of major nutrients (Joshi and Deo, 1975; Vista *et al*., 2021).Farmers' must emphasize on site specific nutrient management having balance application of chemical fertilizers along with making best use of organic resources. Majority of the soil have loam to sandy loam texture which are consider as good soil and suitable for crop production. Therefore, an integrated nutrient management practices where all sources of plant nutrients (mineral fertilizers, compost, bacterial fertilizers) can be scientifically used for sustainable agriculture growth. Sustainable plant nutrients management leads to improve productivity thereby improve the livelihood of the people and better environment since it takes into consideration of the factors that may have negative effect on soil and environment (Carson, 1992; Serchan and Gurung, 1995).

CONCLUSIONS

The major soil orders found in Nalgad municipality on the basis of USDA soil taxonomy were Entisols (15.13 %) and Inceptisols (83.60%). In the context of soil available nutrients, organic matter content in the soil ranges from very low to high, total nitrogen ranges from very low to very high with high level in major proportions, available phosphorus with low to very high range and available potassium content ranges from low to very high. Soils of Nalgad municipality are dominated by Inceptisols characterized by moderate fertility status from agriculture perspective. Soil analysis of study area showed that the soil of Nalgad is suitable for most of sub-tropical crops in lower parts and warm temperate and temperate crops in upper part of municipality but care should be given in organic matter management by reducing their loss through erosion, improving the availability of nitrogen, phosphorous and to some extent potassium and pH management. Organic matter should be enriched in low level region and reclamation of moderately to very high acidic soil is recommended. The area having very low, low, medium and high status of major nutrients, 120 %, 100 %, 75% and 50% respectively of recommended dose of fertilizers should be recommended for adequate supply of nutrients for crops and no need of any fertilizers to those area having very high status of nutrients. Major nutrients status in soil were found to be good but integrated land management practices should be encouraged that include agroforestry, animal husbandry, sloping agricultural land technology and other sustainable soil management technology for improving land productivity. This study is not sufficient

for proper crop zoning but should be used for further crop zoning initiative and policy intervention in agricultural commercialization of the Municipality.

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PERCEPTIVE STUDY ON POLICY INTERLINKAGE AND INSTITUTIONAL ARRANGEMENT OF AGROBIODIVERSITY WITH CLIMATE CHANGE, FOOD AND NUTRITION

S. Khanal[1]*, B.K. Joshi[2], R.K. Shrestha[3], S. Shivakoti[4], A. Bhusal[5] and S. Shrestha[5]

ABSTRACT

A study was conducted to find out interlink, assessing the implementation status, challenges and opportunities in mainstreaming the nexus of agro biodiversity, food and nutrition and climate change in policies and programs. An online survey tool (mwater) was used to deploy the pretested questionnaire to different professionals of Nepal. Out of 500 deployment, 54 responses were obtained. In most of the questions farmers were unable to decide the extent of interlink and implementation status, however, other professional groups perceived the linkage to be weak to moderate. Moreover, the implementation status of these policies were discerned to be less satisfactory. The opportunities and challenges are to be considered while plotting the action. For doing so, institutional setup for implementation and monitoring need to strengthen with wide consultation from policy formulation to implementation, impact assessment and review for having greater impacts on farming communities.

Keywords: Agro biodiversity, challenges, consultation, implementation, monitoring, nexus

INTRODUCTION

Nepal is rich in biodiversity and it ranks 49th in terms of world biodiversity, the 31st and the 10th in flowering plant diversity in the world and Asia respectively (Butler, 2016). Moreover, Nepal ranks the 27th position on the basis of per unit area, with 1.16 Biodiversity (BioD) index per land area where Brunei ranks 1st with an 18.68 BioD index per land area. Though the country occupies only 0.03% of the global area but harbors over 3% and 1% of the world's known flora and fauna, respectively. There are 118 types of ecosystems with 75 vegetation types, 35 forest types and 5 rangeland ecosystems (MoFSC, 2014). Among 24,300 total species in the country, 28% are agricultural genetic resources (AGRs), termed as agro biodiversity. There are 12 agro

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ecosystems supporting 1026 species under crop component, 510 under forage, 35 under livestock, 250 under the aquatic animal, 17 under aquatic plant, 3,500 under insect and 800 under microorganism. An estimated loss of agro biodiversity is 40%, however, farmers have reported up to 100% loss of AGRs in some areas for a particular species (Joshi *et al*. 2020).

Agro biodiversity is the foundation of supplying diversified and nutritious foods to people of all age groups. It is also crucially important for sustainable and resilient agriculture and food system in the context of the changing climate. Moreover, agro biodiversity is the source of food and nutrition security and livelihood of millions of smallholders worldwide. Despite its multiple benefits, inadequate substantive policy and institutional support in the face of competing market and other pressures have resulted in the rapid loss of agro biodiversity primarily through the replacement of local crop varieties and landraces by modern high-yielding varieties. This has threatened the food and nutrition security and the livelihood of small and marginal farmers (Maharjan *et al*. 2011).

Nepal is a signatory of various international conventions, treaties, and agreements related to the conservation, access, exchange, and use of agro biodiversity. With this and increased awareness and realization, the government has made some efforts to conserve and use agricultural plant genetic resources (Gauchan *et al*. 2017). Several global initiatives recognize the nexus between agriculture, biodiversity, and nutrition and the nexus between agriculture, biodiversity, and climate change and call for greater mainstreaming of agricultural biodiversity into nutrition and climate policy. For example, the latest Global Nutrition Report 2020 calls for increasing and maintaining diversity in production landscapes as a means of contributing to improved nutrition, resilience, and climate adaptation. The UN 2030 Sustainable Development Goals (SDGs) has also envisaged and incorporate the importance of these three dimensions in different SDG goals such as nutrition in Goal 2 (ending hunger and malnutrition), climate change in Goal 13 and agrobiodiversity in Goal 2.5, though specific linkages are not built in single goal. The 15 Development Plan of Nepal (2018/19-2022/23) recognizes the importance of nutrition, climate change and agrobiodiversity, though specific interlinkages are not well spelled out. Presently, limited action points and examples exist for governments to put interlinkage and specific recommendations into practice about this.

Climate change, biodiversity loss and multiple forms of malnutrition are hitting hard to human race and the challenges posed is well known. EAT-Lancet Commission states that the food is the single strongest lever to optimize human health and environmental sustainability on Earth, but is currently threatening both people and planet (EAT, 2019). Half of the world's habitable land surface is occupied by crops and livestock which consume about three quarters of fresh water resources. Moreover, deforestation rate is running at 4 million hectares per year and 3/4shares

of it goes to agriculture in clearing forest for planting crops or raising livestock. Thus agriculture is one of the greater driver of biodiversity loss and contributor to climate change. Moreover, the healthy diets are being replaced by processed and junk foods (FAO, 2019). So, there is a dearth need of adopting an agri-food-systems perspective by identifying the key policies and actions needed to address the challenges of climate change, biodiversity loss and nutrition (HLPE, 2017). Raising awareness of the importance of the agrobiodiversity and its interlinkages with climate change and nutrition amongst all sectors of society, including the public and policy makers and private sectors, and operationalizing the nexus between the three areas into practice is the need of the hour. However, there are limited information and evidence of their interlinkages in Nepal.

The study was carried out to find out the perception of stakeholders on the provisions of the interlink between the major policies related to agrobiodiversity, climate change and food and nutrition along with their implementation status, and pointing out the challenges and opportunities in mainstreaming the nexus in policies and programs.

METHODOLOGY

Different policies related to agrobiodiversity/agriculture were listed out for recording the perception of different stakeholders about the implementation status of these policies and interlink with climate change, food and nutrition and small holder farmers along with institutional arrangements, opportunities and challenges. For doing so, questionnaire was prepared, discussed with key persons and uploaded in an online survey tool, i.e. mWater portal (https://portal.mwater.co/#/). The questionnaire was divided into consent form, respondent profile, perception on implementation status of policies and interlink with climate change and food & nutrition on five point likert scale. Moreover, perception about institutional arrangements were observed as adequate, average, inadequate and can't say. A pre-test was conducted and then the questionnaire were revised. The online survey was requested from 500 relevant persons (farmers, experts, academicians, students, researchers, policymakers, focal persons of the relevant department and ministries). A request was also posted on the Facebook page and other social platform. However, only 54 completed responses were obtained.

The information collected from mWater portal was exported to MS-EXCEL which was then loaded to Statistical Package for Social Science version 21. Descriptive and inferential analysis were done. As responses expected count was less than 5, Fisher exact test was done for observing level of significance for responses at P=0.05 instead of Chi square. The analyzed data were processed and presented in tables, bar diagrams, and pie charts as and where needed. For ranking of gaps, opportunities, and challenges index was calculated based on a percentage of response

for a particular category. Moreover, Cronbach's alpha value was calculated and assessed to check the reliability and internal consistency of results obtained from survey. The value of Cronbach's alpha between 0.755 to 0.966 showed the reliability of results. Consultation workshop was done with experts to validate the results.

RESULTS AND DISCUSSIONS

PROFILE OF RESPONDENT STAKEHOLDERS

Out of 54 respondents , 6% were farmers, 26% were scientists/researchers, 18% each were policy advocates and academicians, 10% were students of masters level (agriculture) and 22 % were extension workers (figure 1).

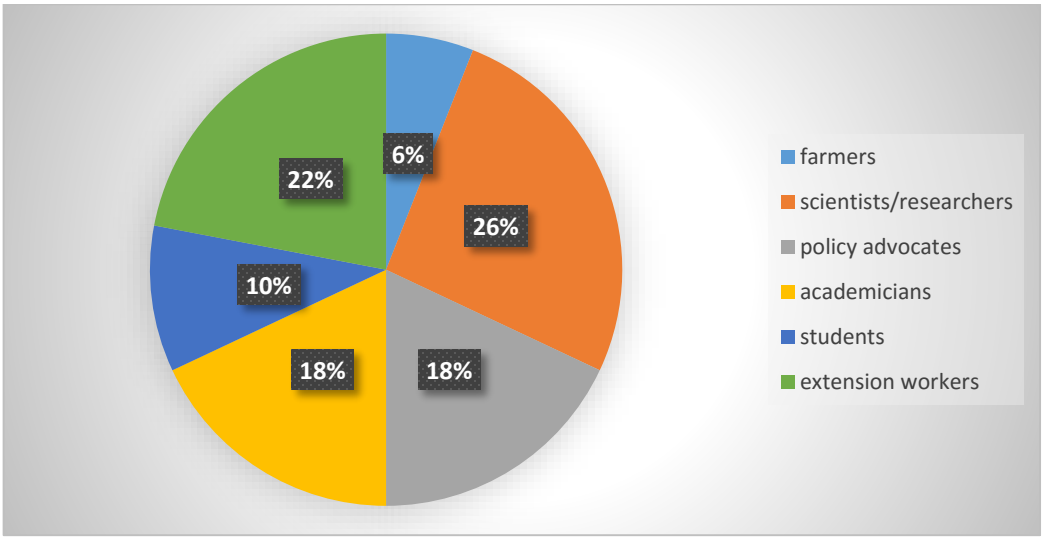

Figure 1. Profession of respondents

Similarly, the engagement of respondents in agriculture/agrobiodiversity, food and nutrition activities, climate related activities, education level and gender is shown in table 1.

Table 1. Characteristics of respondents involved in survey

Characteristics	Farmers (%)	Scientists/ researchers (%)	Policy advocates (%)	Academicians (%)	Students (%)	Extension workers (%)
Engagement in agrobiodiversity /agriculture	100	76.9	44.4	100	100	54.6

Characteristics	Farmers (%)	Scientists/ researchers (%)	Policy advocates (%)	Academicians (%)	Students (%)	Extension workers (%)
Engagement in food and nutrition activities	100	15.4	33.3	75	0	36.4
Engagement in climate related activities	0	7.7	22.3	50	0	9
Education level						
Bachelors	66.7	7.7	44.4	0	100	45.5
Masters and above	33.3	92.3	55.6	100	0	54.5
Gender						
Male	100	92.3	33.3	55.5	80	72.7
Female	0	7.7	66.7	44.5	20	27.3

POLICY INTERLINKAGES OF AGROBIODIVERSITY AND CLIMATE CHANGE

About 68.8% of respondents said Agrobiodiversity policy 1st amendment 2014 and 58.3% said National Biodiversity Strategy and Action Plan 2014-20 are moderately linked with climate change. Apart from these two policies, the majority of respondents felt that there is no linkage between the agrobiodiversity-related policies with climate change (table 2).

Table 2. Response (%) on interlink of agrobiodiversity related policies with climate change

Policy	Strong	Moderate	Weak	No link	Can't say/don't know
Seed Act 1988	2.1	14.6	16.7	60.4	6.3
Agro biodiversity policy 1st amendment 2014	25	68.8	4.2	-	2.1
Agriculture Development Strategy 2015	4.2	8.3	35.4	45.8	6.3
National Seed Policy 1999	3.8	21.2	32.7	30.8	11.5
National Seed Vision 2013-25	4.2	22.9	29.2	35.4	8.3
National Biodiversity Strategy and Action Plan 2014-20	31.3	58.3	8.3	-	2.1
IMISAP 2017	8.3	37.5	22.9	-	31.3
CSB Program Implementation Guideline 2008	29.2	43.8	18.8	-	8.3

Policy	Strong	Moderate	Weak	No link	Can't say/don't know
CSB Establishment Operational Guideline 2015	30.6	51	10.2	-	8.2

Statistical difference was noted in the response of professionals stating about the interlink of Seed Act 1988 ($P<0.05$), Agricultural Development Strategy 2015 ($P<0.05$) and National Seed Policy 1999 ($P<0.05$) with climate change aspects. Farmers and extension workers believe that there's no linkage of Seed Act 1988 with climate change. Scientists/researchers and policy advocates found weak linkage whereas academicians and students feel moderate linkage in this regard. Similarly for Agriculture Development Strategy 2015, farmers were unable to say, extension workers felt no linkage whereas other groups stated moderate linkage with climate change. Moreover for National Seed Policy 1999, farmers said no linkage existed with climate change, policy advocates and extension workers found weak linkage whereas other groups found moderate linkage. Detail is shown in table 3.

Table 3. Response of different professionals stating the linkage of agrobiodiversity related policies with climate change

Policy	Farmer	Scientists/researchers	Policy advocate	Academicians	Students	Extension workers	Fisher exact test
Seed Act 1988	1	2	2	3	3	1	11.26*
Agro biodiversity policy 1st amendment 2014	0	2	3	3	2	3	2.49ns
Agriculture Development Strategy 2015	0	2	2	2	2	1	12.79*
National Seed Policy 1999	1	3	2	3	3	2	12.38*
National Seed Vision 2013-25	0	3	4	3	4	2	8.21ns
National Biodiversity Strategy and Action Plan 2014-20	2	4	3	1	4	3	8.20ns
IMISAP 2017	0	4	4	4	0	4	6.23ns
CSB Program Implementation Guideline 2008	1	2	2	3	3	1	9.38ns
CSB Establishment Operational Guideline 2015	1	2	2	3	3	1	2.01ns

Note: the numbers in the table signifies median values where 0=can't say/don't know, 1=no linkage, 2=weak linkage, 3=moderate linkage, 4= high linkage, ns= not significant, *=P<0.05

About 51% of respondents said National climate change policy 2019 to be moderately linked with agrobiodiversity which was 45.8% for the National Adaptation Plan of Action 2010. Moreover, 50% perceived weak linkage of National Environment policy 2019 with agrobiodiversity and 47.9% voted the interlinkage of Environment protection act 2019 to be weak in this regard (**figure** 2).

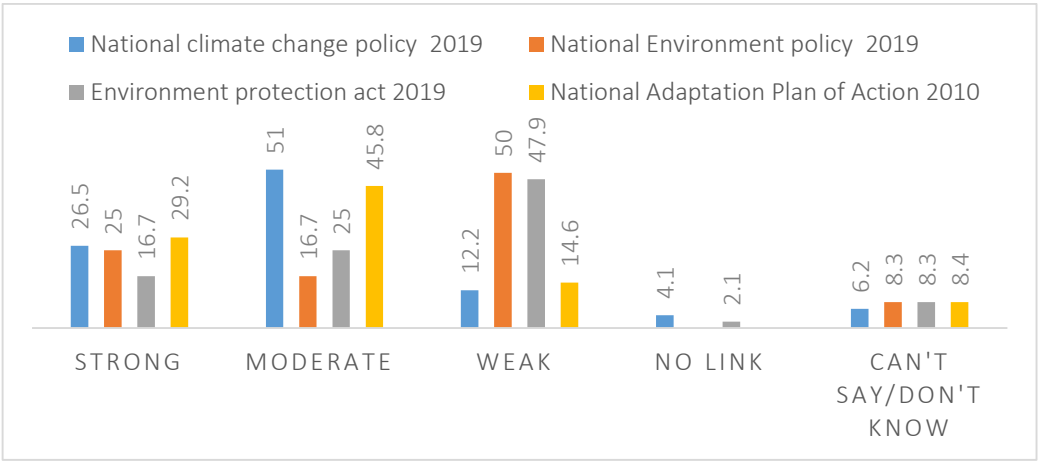

Figure 1. Response (%) on interlink of climate change-related policies with agrobiodiversity

POLICY INTERLINK OF AGROBIODIVERSITY RELATED POLICIES WITH FOOD AND NUTRITION

Talking about the interlinkage of agrobiodiversity-related policies with food and nutrition, most of the respondents felt that there is a moderate linkage between these sectors as shown in **table** 4.

Table 4. Response (%) on interlink of agrobiodiversity related policies with food and nutrition

Policy	Strong	Moderate	Weak	No link	Can't say/don't know
Seed Act 1988	29.2	54.2	12.5		4.1
Agro biodiversity policy 1st amendment 2014	27.1	62.5	6.3		4.1
Agriculture Development Strategy 2015	40.8	44.9	10.2	2	2.1
National Seed Policy 1999	29.2	50	16.7		4.1

Policy	Strong	Moderate	Weak	No link	Can't say/don't know
National Seed Vision 2013-25	28.6	51	16.3		4.1
National Biodiversity Strategy and Action Plan 2014-20	14.6	68.8	6.3	2.1	8.2
IMISAP 2017	4.2	60.4	14.6		20.8
CSB Program Implementation Guideline 2008	33.2	58.3	2.1	2.1	4.2
CSB Establishment Operational Guideline 2015	34.7	55.1	4.1		6.1

Significant difference was observed while recording the response on interlinkage of agrobiodiversity related policies with food and nutrition with respect to National Biodiversity Strategy and Action Plan 2014-20 ($P<0.05$), CSB Program Implementation Guideline 2008 ($P<0.05$) and CSB Establishment Operational Guideline 2015 ($P<0.05$). Farmers were unable to decide about the extent of interlinkage with these policies. Scientists/researchers and policy advocates felt high linkage, academicians felt no linkage, students were undecided for National Biodiversity Strategy and Action Plan 2014-20 and felt weak linkage for CSB Program Implementation Guideline 2008 and CSB Establishment Operational Guideline 2015. Similarly, extension workers said that these policies are moderately linked with food and nutrition (table 5).

Table 5. Response of different professionals stating the linkage of agrobiodiversity related policies with food and nutrition

Policy	Farmer	Scientists/researchers	Policy advocate	Academicians	Students	Extension workers	Fisher exact test
Seed Act 1988	0	4	3	4	1	2	5.49ns
Agro biodiversity policy 1st amendment 2014	0	2	4	3	3	3	5.92ns
Agriculture Development Strategy 2015	0	3	4	4	3	4	9.14ns
National Seed Policy 1999	0	4	3	4	3	1	5.27ns
National Seed Vision 2013-25	0	4	4	3	2	2	4.20ns
National Biodiversity Strategy and Action Plan 2014-20	0	4	4	1	0	2	11.07*
IMISAP 2017	0	3	3	1	3	1	5.03ns
CSB Program Implementation	0	4	4	1	2	2	12.67*

Policy	Farmer	Scientists/researchers	Policy advocate	Academicians	Students	Extension workers	Fisher exact test
Guideline 2008 CSB Establishment Operational Guideline 2015	0	4	4	1	2	2	12.82*

Note: the numbers in the table signifies median values where 0=can't say/don't know, 1=no linkage, 2=weak linkage, 3=moderate linkage, 4= high linkage, ns= not significant, *=P<0.05

As shown in **table** 06, the majority of respondents felt that the policies related to food and nutrition are moderately linked to agrobiodiversity.

Table 6. Response (%) on interlink of policies and legislation related to food and nutritional security with agrobiodiversity

Policy	Strong	Moderate	Weak	No linkage	Can't say/don't know
Multi sectorial nutritional plan II (2018-22)	23.4	46.8	17	4.3	8.5
National nutritional policy and strategy 2004	23.4	55.3	14.9	2.1	4.3
Zero hunger challenge national action plan (2016-25)	19.1	51.1	17	6.4	6.4
Food and nutritional security plan of action 2013	21.3	53.2	17	2.1	6.4
The right to food and food sovereignty act 2018	27.7	46.8	19.1		6.4

While observing the response of different professional groups stating the interlinkage of food and nutrition related policies with agrobiodiversity, significant difference was not observed in any of the cases. Detail is shown in table 07.

Table 07. Response of different professionals stating the linkage of food and nutrition related policies with agrobiodiversity

Policy	Farmer	Scientists/researchers	Policy advocate	Academicians	Students	Extension workers	Fisher exact test
Multi sectorial nutritional plan II (2018-22)	0	4	3	1	1	4	1.59ns
National nutritional policy and strategy	0	3	3	2	0	4	4.26ns

Policy	Farmer	Scientists/researchers	Policy advocate	Academicians	Students	Extension workers	Fisher exact test
2004							
Zero hunger challenge national action plan (2016-25)	0	3	2	1	1	4	4.33ns
Food and nutritional security plan of action 2013	0	3	3	3	0	4	3.33ns
The right to food and food sovereignty act 2018	0	3	4	3	0	4	5.60ns

Note: the numbers in the table signifies median values where 0=can't say/don't know, 1=no linkage, 2=weak linkage, 3=moderate linkage, 4= high linkage, ns= not significant, *=P<0.05

INSTITUTIONAL ARRANGEMENT RELATED TO AGROBIODIVERSITY

With regards to the institutional arrangements related to agrobiodiversity, the majority of respondents felt the inadequacy in geographical coverage and number (48%), staffs strength and capacity (70%), and impacts produced (76%) (**figure** 3). While coverage of content and subjects as well as a collaboration was said to be average by 58% and 52% of respondents respectively.

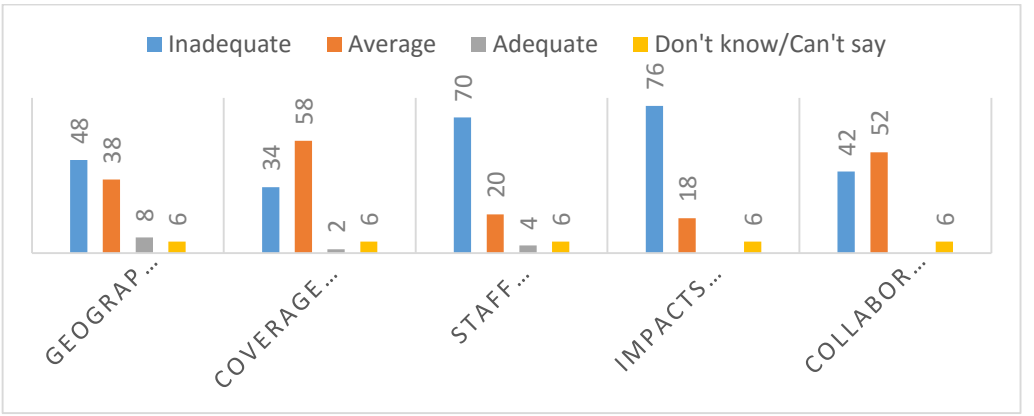

Figure 3. Response (%) on status of institutional arrangements related to agrobiodiversity

While observing the response on institutional arrangement related to agrobiodiversity across different professional groups significant difference was seen only for impacts produced so far (P<0.05). Farmers and students were undecided, policy advocates and extension workers felt the impacts were inadequate, moreover, scientists/researchers and academicians felt the impacts produced from current institutional arrangement were average. Detail is shown in table 08.

Table 8. Response of different professional groups on status of institutional arrangements related to agrobiodiversity

Profession	Farmers	Scientist/researcher	policy advocate	Academicians	Students	extension workers	Fisher exact test
Geographical coverage and number	3	3	1	3	2	3	8.64ns
Coverage of the contents and subjects	0	1	0	0	0	0	3.67ns
Staff strength and capacity	0	2	1	3	3	3	8.42ns
Impacts produced so far	0	2	1	2	0	1	13.03*
Collaboration with other related institutions	0	1	1	0	0	1	8.01ns

Note: the numbers in the table signifies median values where 0=can't say/don't know, 1=inadequate, 2=average, 3=adequate, ns=not significant, *=P<0.05

IMPLEMENTATION STATUS

As per the respondents the implementation status of policies regarding agrobiodiversity is not in the direction as anticipated. Most of the policies are perceived to be slightly effective (**table** 09).

Table 9. Response (%) on implementation status of agrobiodiversity related policies

Policy	Highly effective	Moderately effective	Slightly effective	Ineffective	Can't say/don't know
Seed Act 1988	4.2	20.8	47.9	20.8	6.2
Agro biodiversity policy 1st amendment 2014		18	60	8	14
Agriculture Development Strategy 2015		16	52	26	6
National Seed Policy 1999	2	24	50	16	8
National Seed Vision 2013-25	2	14	58	18	8
National Biodiversity Strategy and Action Plan 2014-20		18	56	12	14
IMISAP 2017		10	40	6	44
CSB Program Implementation Guideline 2008	4	26	46	6	18

Policy	Highly effective	Moderately effective	Slightly effective	Ineffective	Can't say/don't know
CSB Establishment Operational Guideline 2015	2	24	46	6	22

While observing the response on implementation status of agrobiodiversity related policies, significant difference was observed with Agriculture Development Strategy 2015 ($P<0.05$) and National Seed Vision 2013-25 ($P<0.05$). Detail is shown in table 10.

Table 10. Response of different professional groups about the implementation of agrobiodiversity, related policies

Policy	Farmer	Scientists/researchers	Policy advocate	Academicians	Students	Extension workers	Fisher exact test
Seed Act 1988	0	4	0	3	2	2	2.17ns
Agro biodiversity policy 1st amendment 2014	0	3	0	3	0	3	3.62ns
Agriculture Development Strategy 2015	0	1	2	1	2	1	12.68*
National Seed Policy 1999	0	4	1	2	2	2	4.27ns
National Seed Vision 2013-25	0	3	2	2	2	2	10.63*
National Biodiversity Strategy and Action Plan 2014-20	0	2	2	3	3	1	8.46ns
IMISAP 2017	0	2	1	1	0	1	5.21ns
CSB Program Implementation Guideline 2008	0	3	2	4	3	3	4.32ns
CSB Establishment Operational Guideline 2015	0	4	2	3	1	2	3.39ns

Note: the number represents the median value where 0 = “Can’t say/don’t know, 1 =Ineffective, 2 = slightly effective, 3=moderately effective and 4=highly effective

POLICY CONSTRAINTS, CHALLENGES, AND OPPORTUNITIES

The major opportunities as perceived by respondents for increasing policy interlinkage for improving climate resiliency were adaptation and mitigation strategies to combat climate change, linking climate change with income generation, and enhanced livelihood opportunities. However, certain challenges are hindering cash in these opportunities. The major challenges perceived in this regard were

uneven impacts seen across regions and population groups, adaptation and mitigation strategies being site-specific and fewer priorities given to marginal communities (table 11).

Table 11. Opportunities and challenges of increasing policy interlinkage for improving climate resiliency

Opportunities	Index	Rank	Challenges	Index	Rank
Awareness raising	0.16	4th	Less priority to marginal communities	0.23	3rd
Enhanced livelihood opportunities	0.20	3rd	Adaptation and mitigation strategies are site specific	0.27	2nd
Adaptation and mitigation strategies followed	0.27	1st	Uneven impacts across regions and population groups	0.30	1st
Link climate change adaptation with income generation	0.23	2nd	Lack of well defined support in terms of knowledge and technology transfer	0.19	4th
Ensure participation of local communities	0.14	5th			

The major opportunities as perceived by respondents for increasing policy interlinkage for improving food and nutritional security were mainstreaming neglected underutilized species in food and nutrition plan, value addition of minor crops, and importance to food sovereignty by the constitution of Nepal. The major challenges perceived to hinder cashing opportunities were difficult geography and poor infrastructure, change in land use pattern, and loss of biodiversity (**table** 12).

Table 12. Opportunities and challenges of increasing policy interlinkage for improving food and nutritional security

Opportunities	Index	Rank	Challenges	Index	Rank
Mainstreaming NUS	0.22	1st	Out migration of youth	0.16	3rd
Increased awareness	0.18	3rd	Change in dietary pattern	0.13	5th
Enhanced livelihood opportunities	0.17	5th	Difficult geography and poor infrastructure	0.22	1st
Achieve food sovereignty	0.18	3rd	Change in land use pattern	0.19	2nd
Value addition of	0.22	1st	Loss of biodiversity	0.16	3rd

Opportunities	Index	Rank	Challenges	Index	Rank
minor crops					
Community based local participation	0.01	6th	Climate change	0.11	6th
Integration of crops, livestock and fisheries	0.01	6th	Armed conflicts in the past	0.01	7th
One health program	0.01	6th	Social dispute and disintegration	0.01	7th

The major opportunities for increasing policy interlinkage so as to improve the conditions of small holder farmers were perceived that the small holders are better placed to manage agrobiodiversity, agrobiodiversity provides livelihood security to small holders and resource endowed farmers maintain agrobiodiversity. The major challenges perceived to hinder cashing opportunities were low initial demand of neglected underutilized species, the high transitional cost for small holders to bear, and limited access to technical knowledge (table 13).

Table 13. Opportunities and challenges of increasing policy interlinkage for improving condition of small holder farmers

Opportunities	Index	Rank	Challenges	Index	Rank
Smallholder supply great part of food stuffs consumed	0.2	4th	Low initial demand of NUS	0.28	1st
Small holders are closely placed to manage agro biodiversity	0.3	1st	High transitional cost	0.24	2nd
Resource endowed farmers maintain agrobiodiversity	0.23	3rd	Limited capital resource	0.22	4th
Agrobiodiversity provides livelihood security to small holders	0.25	2nd	Limited access to technical knowledge	0.24	2nd
Sustainable management of resources at community level	0.01	5th	Small scale production and poor government support	0.01	5th

CONCLUSIONS

Awareness on policies related to agriculture is quite poor across the country. The majority of these policies do not recognize the agrobiodiversity at the core having linkage with climate change and nutrition in the sense that conservation of agrobiodiversity has positive impact on climate change adaptation and nutritional outcomes. Moreover, the level of effectiveness and implementation status is either

mostly less effective, ineffective and few of the policies are moderately effective. The contribution of such policies to smallholders is very negligible. Interlinkages among these policies should be inbuilt targeting conditional beneficiaries and specific locations. Institutional setup for implementation and monitoring need to strengthen. Wide consultation during policy formulation and implementation, regular impact assessment, and review are necessary to get the greater impact of these policies on farming and consumer communities. Policies should be effectively developed and implemented so that a system-based approach could be in place for conservation and utilization of agrobiodiversity, food and nutrition security, and mitigation of climate changes targeting smallholder farmers.

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EVALUATION OF RAPESEED GENOTYPES AGAINST ALTERNARIA BLIGHT UNDER FIELD CONDITIONS IN NAWALPARASI-WEST, NEPAL

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ABSTRACT

Alternaria blight disease causes both yield and quality loss in Brassica crops. A field evaluation of ten rapeseed genotypes against Alternaria blight disease was conducted during November 2018 to February 2019 in Parasi, Nawalparasi-west district. Experiment was laid out in a randomized complete block design with individual plot size of 2.25 m^2 with three replications. Post-harvest in-vitro seed infection test was done in a completely randomized design with four replications. Disease scoring was done as percentage of leaf area and pod infection on individual 15 sample plants per plot at seven days intervals. Genotype ICT 2001-35 was found moderately resistant based on categorization of mean leaf AUDPC (308.52) and mean pod infection AUDPC values (391.48) with low seed infection (12.50%). Preeti, Bikash and Pragati showed highly susceptible reactions to both leaf blight and pod infection. Therefore, genotype ICT 2001-35 could be used in a varietal improvement program for disease resistance against Alternaria blight.

Keywords: Alternaria blight, AUDPC, genotypes, moderately resistant, rapeseed

INTRODUCTION

Oilseed is one of the important cash crops of Nepal. It is mostly grown after monsoon maize in upland conditions and after early rice in lowland of terai, inner terai and mid-hills (Ghimire *et al.,* 2000). It occupied 258,141 hectares of land with the production of 278,325 metric tonnes and productivity of 1.08 mt/ha in 2019/20 (MoALD, 2021). Among the oilseed crops, rapeseed (*Brassica campestris* var. *toria*) is the dominant oilseed crop that occupies about 85% of the total oilseed area in Nepal (Basnet, 2005). A wide gap exists between the potential yield and the yield realized at the farmer's field due to a number of biotic and abiotic stresses. Among the biotic factors, Alternaria blight disease caused by *Alternaria brassicae* (Berk.) Sacc. has been reported from all the continents of the world causing both yield and quality loss (Sharma and Pandey, 2013).These days, it has become one of the major diseases in Terai and inner Terai regions of Nepal (Shrestha and Chaudhary, 1999). Shrestha *et al*. (2005) reported an average yield loss in the range of 32-57% due to the disease in Nepal. In addition to direct losses in yield, the disease adversely affects seed quality by reducing seed size, seed discolouration and reduction in oil content (Prasad,

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2006). Alternaria is a very destructive pathogen causing a widespread destruction in vegetables and other economically important crops (Mamgain *et al.*, 2013). The environmental conditions 80-90% RH, maximum temperature ranging from 18-25 °C, minimum temperature ranging from 10-14 °C and 14-15 hour wetness period daily with dews from 6 pm to 9 am during the month of December and January, favored the disease development of *Alternaria* leaf blight in mustard (Shrestha *et al.*, 2005).

Alternaria blight is the most destructive disease and no well characterized source of resistance is available (Labana *et al.*, 2013). Mamgain *et al.* (2013) reported keeping in view the various health hazards to human beings by chemical control, growing disease resistant varieties is more economical, eco−friendly and safe. Thus, the objective of this study was to assess the level of resistance in different rapeseed genotypes against Alternaria blight disease under field conditions of Nawalparasi-west, central inner terai district of Nepal.

METHODOLOGY

FIELD EXPERIMENT

Field experiment was conducted in Ramgram Municipality-4, Nawalparasi-west during November 2018 to February 2019 and in−vitro test for seed after harvest was conducted at plant pathology laboratory of Agriculture and Forestry University, (AFU), Rampur, Chitwan. Field experiment was conducted in a randomized complete block design (RCBD) with 3 replications. Individual plot size was 2.25 m^2 (1.5 m × 1.5 m) and the area of the research field was 107.38 m^2. There were six rows of 1.5 m length/plot at a distance of 10 cm apart. The susceptible check variety, "Pragati" was sown in a single row around the whole field. Interblock and interplot spacing were 80 cm and 40 cm, respectively. Ten rapeseed genotypes (Preeti, Bikash, Pragati, Unnati, Uttara Tori, Acc # 9118, Acc # 9109, Local Kalo Tori, Morang Tori 2, and ICT 2001-35) were randomly allocated in each block. Analysis of variance (ANOVA) was used to test differences among the treatments and means separated using Duncan's multiple range test (DMRT) at 5% level of significance.

DISEASE ASSESSMENT

Disease observations were taken from 15 plants selected randomly from six central rows of each plot. The plants were tagged for further scoring. Disease intensity was scored on a 0-5 scale (Sharma and Kolte, 1994) as below.

0 = no symptoms
1 = 1-10% leaf area covered by spots
2 =11-25% leaf area covered by spots
3 = 26-50% leaf area covered by spots
4 = 51-75% leaf area covered by spots
5 = >75% leaf area covered by spots

The severity on pods was also measured from the sample plants after initiation of pod formation. Disease scoring scale for severity on pod was 0-5 scale (Sapkota *et al.*, 2002) as follows:

0 = No symptoms
1 = Infection on leaf and started on stem
2 = 5% area of stem covered by lesions
3 = 6-25% area of stem covered by lesions, initiation of lesion on siliques
4 = 50% area of stem covered by lesions and sufficient lesions on siliques
5 = >50% area of inflorescence and siliques covered by lesions

The percent disease severity (%) of foliar diseases at each scoring was calculated by using following formula developed by (Sharma and Kolte, 1994):

$$\text{Disease severity (\%)} = \frac{\text{Sum of all numerical ratings}}{\text{Total number of plants observed} \times \text{maximum rating}} \times 100$$

Disease severity was calculated/plant and mean severity was computed/plot. The area under disease progress curve (AUDPC) value was calculated by using the following formula as given by Das *et al*. (1992).

$$AUDPC = \sum_{i=1}^{n-1} [\{(Y_i+Y_{(i+1)})/2\}\times(t_{(i+1)}.t_i)]$$

Where, Y_i= disease severity on the i^{th} date
Y_{i+1}= disease severity on the $i+1^{th}$ date
N= number of dates on which disease was recorded

Disease severity was measured on leaf and pods separately. Total AUDPC, mean AUDPC and AUDPC per day were also calculated. Based on mean leaf AUDPC values and mean pod AUDPC values obtained from the observation of ten genotypes, a scale of mean leaf and pod AUDPC value was proposed to categorize the genotypes into three resistance levels as below:

Mean leaf AUDPC value	Mean pod AUDPC value	Resistant category	Code
301-350	350-400	Moderately resistant	MR
351-400	401-450	Susceptible	S
>400	>450	Highly susceptible	HS

SEED BORNE INFECTION

Randomly selected 400 seeds of each test genotype were tested for the presence of pathogen. Twenty-five seeds were placed at equidistance per Petri dish with two layers of moistened blotting paper. Seeds plated in the Petri dishes were incubated at 25±1ºC for seven days. The plates were transferred to a deep freezer at -20ºC for 12 hours after 24 hrs of incubation and re-incubated at 25±1ºC for 6 days. On the 7th day of incubation period the seeds were examined thoroughly under different magnification of stereomicroscope for the growth of *Alternaria brassicae* on them. Seed infection percentage was calculated using the following formula:

$$\text{Seed infection \%} = \frac{\text{Number of infected seeds} \times 100}{\text{Total number of seeds observed}}$$

Saprophytic and pathogenic species were identified based on the size of conidia. Conidia are distinctive; darkly pigmented, oval and both horizontal and vertical internal walls (septa). Conidia having elongated terminal cells ("beaks" or "tails") are generally pathogenic whereas saprophytic *Alternaria* spp. do not have beaks.

STATISTICAL ANALYSIS

Analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) were done by using statistical software R-STAT; correlation analysis was done using MS-Excel 2010.

RESULTS

DISEASE INCIDENCE AND SEVERITY

Symptoms of Alternaria blight appeared in all rapeseed genotypes 63 to 70 days after sowing (DAS). Disease incidence at 63 DAS was found highest in Preeti (23.33%) and lowest was seen in Morang Tori-2 (4.56%) which was at par with Local Kalo Tori (8.31%).

Ten rapeseed genotypes varied considerably in Alternaria blight disease at 82, 89 and 96 DAS. Disease severity observed at 82 DAS was found highest in Preeti (51.11%) followed by Bikash (50.67%), Pragati (49.78%) and Uttara Tori (48.89%). Minimum leaf severity was observed in ICT 2001-35 (36.44%) which was at par with ACC # 9109 (40.89%) and Local Kalo Tori (40.89%).

Disease severity observed at 89 DAS was found highest in Bikash (72.88%) which was at par with Preeti (66.66%), Pragati (65.77%) and Unnati (65.77%). Minimum leaf severity was found in ICT 2001-35 (52.88%) which was at par with Morang Tori-2 (56.00%), Local Kalo Tori (56.00%) and ACC # 9109 (57.33%), respectively (Table 1).

Disease severity observed at 96 DAS was found highly significant among genotypes with highest being in Bikash (90.22%) which was at par with Preeti (88.44%) and lowest severity was found in ICT 2001-35 (72.00%), which was at par with Morang Tori-2 (76.44%), respectively. Minimum disease severity in leaf is found in genotype ICT 2001-35.

Table 1. Severity of Alternaria blight disease in rapeseed genotypes in Parasi, Nawalparasi-west, Nepal during Nov 2018 to Feb 2019

Genotypes	82 DAS	89 DAS	96 DAS
Preeti	51.11^{a}	66.66^{ab}	88.44^{a}
Bikash	50.67^{a}	72.88^{a}	90.22^{a}
Pragati	49.78^{ab}	65.77^{abc}	88.00^{a}
Unnati	45.33^{abc}	65.77^{abc}	84.88^{ab}
Uttara Tori	48.89^{ab}	59.55^{bcd}	81.77^{ab}
ACC # 9118	43.56^{abc}	59.55^{bcd}	82.66^{ab}
ACC # 9109	40.89^{bc}	57.33^{bcd}	77.33^{bc}
Local Kalo Tori	40.89^{bc}	56.00^{cd}	82.22^{ab}
Morang Tori 2	42.22^{abc}	56.00^{cd}	76.44^{bc}
ICT 2001-35	36.44^{c}	52.88^{d}	72.00^{c}
LSD	8.21	8.78	8.43
p-value	0.01568	0.00332	4.62e-03
Grand mean	44.97	61.24	82.4
SEM(±)	1.25	1.34	1.26
CV (%)	10.64	8.35	5.96

DAS: Days after sowing, CV: Coefficient of variation, LSD: Least significant difference, Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance, SEM(±): Standard error of mean

DISEASE SEVERITY IN POD

Ten rapeseed genotypes varied considerably in pod severity in 89, 96 and 103 DAS. The pod severity observed at 82 DAS was found non-significant. The disease severity at 89 DAS was found highest in Bikash (66.67%) which was at par with Preeti (62.66%),

Pragati (61.33%) and Unnati (59.11%). Lowest pod severity was found in ICT 2001-35 (47.56%) which was at par with ACC # 9118 (51.11%), and Morang Tori-2 (52.89%). Pod severity at 96 and 103 DAS was found highest in Preeti (81.78%, 93.78%) which was at par with Bikash, Pragati and Unnati. Lowest pod severity was found in ICT 2001-35 (63.33%) in 96 DAS and in Morang Tori-2 (83.11%) at 103 DAS.

Table 2. Disease severity in pod of rapeseed genotypes in Parasi, Nawalparasi-west, Nepal during Nov 2018 to Feb 2019

Genotypes	82 DAS	89 DAS	96 DAS	103 DAS
Preeti	39.11	62.66^{ab}	81.78^{a}	93.78^{a}
Bikash	35.11	66.67^{a}	75.11^{ab}	90.67^{abc}
Pragati	32.00	61.33^{ab}	73.33^{ab}	90.22^{abc}
Unnati	40.00	59.11^{abc}	74.22^{ab}	91.56^{ab}
Uttara Tori	38.67	53.33^{bc}	73.78^{ab}	86.33^{bcd}
ACC # 9118	28.44	51.11^{bc}	71.11^{bc}	90.88^{abc}
ACC # 9109	35.56	55.56^{abc}	67.56^{bc}	90.67^{abc}
Local Kalo Tori	30.67	56.44^{abc}	68.00^{bc}	84.44^{cd}
Morang Tori 2	35.11	52.89^{bc}	71.84^{bc}	83.11^{d}
ICT 2001-35	28.44	47.56^{c}	63.33^{c}	85.33^{bcd}
LSD		10.93	8.52	5.88
p-value	NS	0.0468	0.0204	0.0157
Grand mean	34.31	56.67	71.93	88.7
SEM(±)	1.18	1.39	1.15	0.83
CV (%)	17.43	11.24	6.91	3.86

DAS: Days after sowing, CV: Coefficient of variation, LSD: Least significant difference, Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance, SEM(±): Standard error of mean, NS: Non-significant

DISEASE RESISTANCE/SUSCEPTIBILITY OF RAPESEED GENOTYPES

According to mean leaf infection, AUDPC values Preeti, Bikash and Pragati were highly susceptible, Unnati, Uttara Tori, ACC # 9118 were susceptible and ACC # 9109, Local Kalo Tori, Morang Tori-2, and ICT 2001-35 were moderately resistant against Alternaria blight disease of rapeseed. Based on the mean pod infection AUDPC values, Preeti, Bikash, Pragati, and Unnati were highly susceptible for pod infection; Uttara Tori, ACC # 9118, ACC # 9109, Local Kalo Tori, and Morang Tori-2 were susceptible

and ICT 2001-35 was found moderately resistant for pod infection. ICT 2001-35 was the only genotype found moderately resistant for both leaf blight and pod infection.

Table 3. Categorization of rapeseed genotypes based on mean AUDPC of leaf blight and mean AUDPC of pod infection

Mean leaf AUDPC value	Genotypes	Mean pod AUDPC value	Genotypes	Resistant category
301-350	ACC # 9109, Local Kalo Tori, Morang Tori 2	350-400	ICT 2001-35	Moderately resistant
351-400	Unnati, Uttara Tori, ACC # 9118	401-450	Uttara Tori, ACC # 9118, ACC #9109, Local Kalo Tori, Morang Tori 2	Susceptible
>400	Preeti, Bikash, Pragati	>450	Preeti, Bikash, Pragati, Unnati	Highly susceptible

THOUSAND SEED WEIGHT OF RAPESEED GENOTYPES

There was a significant difference in thousand seed weight among the genotypes. Highest seed weight was found in genotype Bikash (4.76 g) which was at par with ICT 2001-35 (4.68 g), Pragati (4.63 g), Morang Tori-2 (4.57 g), and Uttara tori (4.50 g). Lowest test weight was found in Preeti (4.11 g) followed by Unnati (4.36 g), Local Kalo Tori (4.38 g).

Table 4. Thousand seed weight of rapeseed genotypes in Parasi, Nawalparasi-west, Nepal during Nov 2018 to Feb 2019

Genotypes	1000 seed wt. (g)
Preeti	4.11^{d}
Bikash	4.76^{a}
Pragati	4.63^{abc}
Unnati	4.36^{cd}
Uttara Tori	4.50^{abc}
ACC # 9118	4.49^{abc}
ACC # 9109	4.46^{abc}
Local Kalo Tori	4.38^{bcd}

Genotypes	1000 seed wt. (g)
Morang Tori 2	4.57[ab]
ICT 2001-35	4.68[ab]
LSD	0.27
p-value	0.005
Grand mean	4.49
SEM(±)	0.04
CV (%)	3.51

CV: Coefficient of variation, LSD: Least significant difference, Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance, SEM (±) represents standard error of mean

CORRELATION BETWEEN THE PARAMETERS OF DISEASE AND THOUSAND SEED WEIGHT

Pearson's correlation coefficients were analysed between different variables. Mean AUDPC on pod showed negative correlation with thousand seed weight (-0.346). Final disease severity on pod showed highly significant positive correlation with mean AUDPC on pod infection (0.636) and significant negative correlation with thousand seed weight (-0.151). Mean AUDPC of leaf spot showed highly significant positive correlation with both final disease severity on pod (0.510) and mean AUDPC on pod infection (0.733).

Final disease severity showed highly significant positive correlation with mean AUDPC of leaf spot (0.767), significant positive correlation with final disease severity on pod (0.329), and highly significant positive correlation with mean AUDPC on pod infection (0.741). Disease incidence showed highly significant positive correlation with final disease severity (0.617), mean AUDPC of leaf spot (0.710), mean AUDPC on pod infection (0.665) and significant positive correlation with final disease severity on pod (0.355).

Disease parameters such as disease incidence, final disease severity, mean AUDPC of leaf spot, final disease severity on pod and mean AUDPC on pod showed significant negative correlation with thousand seed weight.

Table 5. Pearson's correlation between different disease parameters and thousand seed weight, Parasi, Nawalparasi-west, Nepal during Nov 2018 to Feb 2019

	Disease incidence	Final disease severity (%)	Mean AUDPC of leaf spot	Final disease severity on pod	Mean AUDPC on pod infection	Thousand seed weight
Disease incidence	1	.617**	.710**	0.355	.665**	-0.158
Final disease		1	.767**	0.329	.741**	-0.159

Severity (%)				
Mean AUDPC of leaf spot	1	.510**	.733**	-0.042
Final disease Severity on pod		1	.636**	-0.151
Mean AUDPC on pod			1	-0.346
Thousand seed weight				1

**: Correlation is significant at the 0.01 level (2-tailed)
* : Correlation is significant at the 0.05 level (2-tailed)

SEED INFECTION

Seeds of all the varieties were infected with *Alternaria* spp., however, the level of infection differed significantly ($p \leq 0.05$). The highest seed infection was found in Preeti (45.25%) which was at par with Unnati (40.75%), Bikash (39.75%) and Pragati (39.25%), and lowest infection was recorded in Local Kalo Tori (12.00%) followed by ICT 2001-35 (12.50%) and Morang Tori-2 (14.75%).

Table 6. Seed infection by *Alternaria brassicae* in ten rapeseed genotypes after harvest,in Parasi, Nawalparasi-west, Nepal during Nov 2018 to Feb 2019

Genotypes	Seed infestation (%)
Preeti	45.25[a]
Bikash	39.75[a]
Pragati	39.25[a]
Unnati	40.75[a]
Uttara Tori	22.25[b]
Acc # 9118	17.75[b]
Acc # 9109	17.75[b]
Local Kalo Tori	12.00[b]
Morang Tori 2	14.75[b]
ICT 200-35	12.50[b]
LSD	11.95
p-value	4.34e-07
Grand Mean	26.2
SEm(±)	2.33
CV(%)	31.6

CV: Coefficient of variation, LSD: Least significant difference, Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance, SEm (±): Standard error of mean

REGRESSION ANALYSIS

There were significant positive linear correlations between mean AUDPC of leaf and seed infection, and between mean AUDPC of pod infection and seed infection percent (Figure 1). According to linear regression equation, it could be said that if there is an unit increase in mean AUDPC of leaf, seed infection percent would have been increased by 0.336 times and if there is an unit increase in mean AUDPC of pod infection, seed infection percent would have been increased by 0.422 times. According to the coefficient of determination, about 83.4% variation in seed infection percent was due to mean AUDPC of leaf and about 85.4% variation in seed infection percent was due to mean AUDPC of pod infection and remaining portion was due to other factors. It is reasonable to conclude that there is positive correlation between mean AUDPC of leaf with seed infection, and mean AUDPC of pod infection with seed infection percent. Increase in mean AUDPC of leaf and mean AUDPC of pod infection significantly increases the seed infection percent.

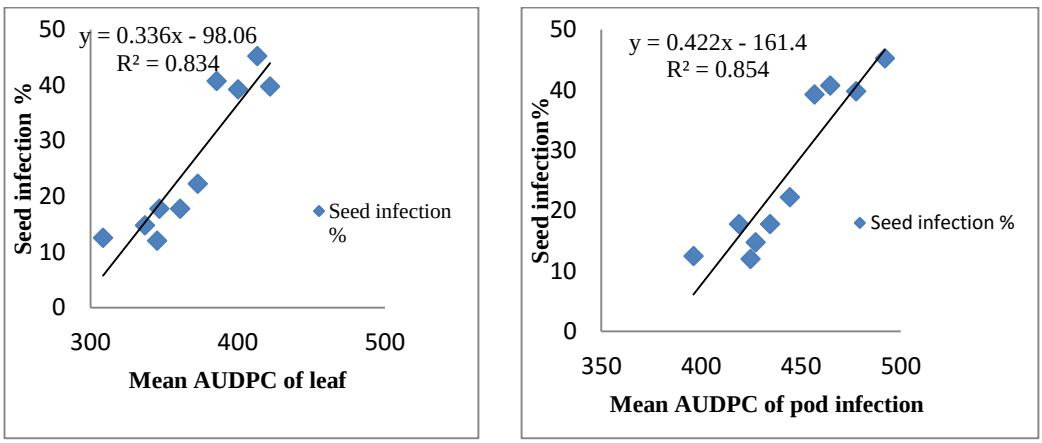

Figure 1. Regression showing the relationship between mean AUDPC of leaf infection and mean AUDPC of pod infection with seed infection in rapeseed genotypes

DISCUSSIONS

Alternaria blight severity in leaf ranged from 72% to 90.22% whereas pod severity ranged from 63.33 to 81.78% at 96 days after sowing. ACC # 9109, Local Kalo Tori, and Morang Tori 2 showed moderately resistant, Unnati, Uttar tori and ACC # 9118 showed susceptible and Preeti, Bikash, Pragati showed highly susceptible reaction to leaf blight whereas Morang Tori 2, Local Kalo Tori, ACC # 9109, ACC # 9118, and Uttara tori showed susceptible and Preeti, Bikash, Pragati, and Unnati showed highly susceptible to pod infection. Only one genotype ICT 2001-35 showed moderately resistant reaction to both leaf blight and pod infection. None of the genotypes was found disease free or resistant. Singh *et al.* (2018) found seven genotypes resistant,

15 genotypes moderately resistant and rest of the genotypes susceptible and highly susceptible but none was disease free among 200 tested genotypes. Talukdar and Das (2017) also have reported four moderately resistant, nine susceptible, 16 moderately susceptible and one highly susceptible but none was highly resistant among 30 tested genotypes against Alternaria blight.

There was significant positive correlation between disease parameters such as final disease severity to mean AUDPC on pod infection but negative correlation between disease parameters and thousand seed weight. This might be due to the fact that blighting of leaves reduced photosynthetic area and pod infection resulting in weight and quality loss of rapeseed. Seed infection by Alternaria species caused shriveling of seeds, which reduced thousand seed weight and seed yield (Sapkota *et al.*, 2002).

CONCLUSIONS

The findings revealed that among ten genotypes tested, Preeti, Bikash and Pragati showed highly susceptible reactions to both leaf blight and pod infection, ICT 2001-35 was moderately resistant to both leaf blight and pod infection but none was resistant. Seed infection percentage was found in the range of 12% to 45.25% in different genotypes. Higher seed infection in Preeti (45.25%) was because of higher disease incidence, higher disease severity, higher mean AUDPC values of leaf and pod infection. The genotype ICT 2001-35 was found moderately resistant to Alternaria leaf spot and pod blight with less disease severity and less post-harvest seed infection. So, it could be used in a varietal improvement program for disease resistance against Alternaria leaf blight.

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CREDIT AND FINANCIAL ACCESS IN NEPALESE AGRICULTURE: PROSPECTS AND CHALLENGES

A. Pandey[1]

ABSTRACT

The credit and financial access are urgent needs for agricultural development. This paper has attempted to find out present status of agricultural credit and their prevalent challenges and problems. The study is fully based on the statistical data, reports and findings of MoALD, MoF, NPC, NRB, and other relevant publications. The Government has targeted to expand agricultural credit through banking and financial institutions (BFIs) by implementing several acts, policies, strategies and programs through NRB, MoALD and MoF. However, constraints like credit ceiling, high value collateral demand, limited redemption facilities, limited agriculture insurance, financial illiteracy, lack of farmer friendly technologies, and poor monitoring and regulation of BFIs are responsible for lower credit expansion. Thus to promote and motivate BFIs and farmers to invest in agriculture, government need to address these challenges. The study also suggests to segregate farmer according to demand of credit volume and expand the branchless banking.

Keywords: BFIs, commercialization, cooperatives, MFIs, production

INTRODUCTION

Nepalese farmers depend on different formal and informal sources for credit facility. The formal sector includes Nepal Rastra Bank (NRB) licensed Bank and financial institutions (BFIs), Microfinance institutions (MFIs), and cooperatives. While the informal sector includes the farmer group, women groups, personal lenders etc.(Gautam *et al*., 2016).

The fifteenth periodic plan has targeted to increase the agriculture growth to 5.4% and productivity by 2024 by increasing the commercialization, competitiveness, mechanization and export promotion (NPC, 2020). Likewise, it has also targeted for the access of credit and financial resources with financial inclusion of farmers including all commercial and small farmers, small, medium and micro cottage, female and youth in all the geographical areas (MoALD, 2015). However, commercialization and competitiveness in agriculture sector is poor due to difficulties in credit access (MoALD, 2015). The agricultural production of Nepal is unable to meet the domestic demand of Nepal. The Table 1 depicts the agricultural production which has increased

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in comparison to past, but very low to meet national demand leading to higher agricultural import.

The minimum per capita annual food requirement set by Food and Agriculture Organization of the United Nations (FAO) shows that existing Nepalese production is insufficient to fulfill the domestic demand. To fulfill this demand, there has been huge import of agricultural commodities in Nepal (MoF, 2021).In 2019/20, around 252.89 billion value of Nepalese currency was expended for importing agriculture commodities. While the agriculture commodities equivalent to 55.19 million was exported in 2019/20 (MoF, 2021).

This insufficient production system, high import, low export and poor competitiveness are challenges as well as opportunities for Nepal to invest in agriculture as profitable sector. The trend of commercialization has increased in Nepal, with the expansion of irrigation facilities and mechanizations. Furthermore, the attraction of farmer toward the animal husbandry is increasing and there are agriculture-friendly government policies which is conducive to carry out the commercialization (NPC, 2020). The government of Nepal has prioritized the agriculture sector for investment, the Agriculture Development Strategy (ADS), fifteenth periodic plan, and NRB directives has enhanced the policies for investment in agriculture sector. The agriculture credit can assist in entire development and promotion of agriculture sector through commercialization, mechanization, competitiveness, import substitution, export promotion and industrialization (MoF, 2021).

Table 1. Status of Major Agricultural Production ('000 Mt)

Category	1994/95	2018/19	2019/20	2020/21*	Productivity (MT/Ha)
Cereals	5440	10686	10935	10926	3.2
Cash crops	2425	6026	6809	6912	12.36
Pulses	202	378	404	397	1.2
Total fruit	398	1018	1249	1305	10.7
Total fresh vegetables	1212	3750	3962	4196	14.7
Milk	941	2092	2301	-	-
Meat	159	346	552	-	-
Eggs (000,000 number)	383	1512	1620	1623	-
Fish	-	-	99	103	-

Source: (MoALD, 2021)

This paper has highlighted the existing credit access and facilities in Nepal for agriculture sector. Furthermore, the paper discusses about the hurdles and challenges prevailed in agriculture credit system. The objective of this paper is to find the gap between credit access and agriculture development in Nepal which may assist the policy maker, academic and related concerns to know the existing situation, loophole in agriculture credit.

METHODOLOGY

The study is completely review based. The paper has explored periodic reports, statistical data, and findings published by government sectors like Ministry of Agriculture and Livestock development (MoALD), Nepal Rastra Bank (NRB), and Ministry of finance (MOF). Likewise, other secondary sources were research articles and publications.

RESULTS AND DISCUSSIONS

AN OVERVIEW OF BANK AND FINANCIAL INSTITUTIONS OF NEPAL

The history of modern and formal financial system was begun in 1937 with the establishment of Nepal Bank Limited. Whereas, the systematic development of financial system was witnessed after establishment of NRB in 1991. Nepal has been following the liberal economic policy and diverse financial system (Dhakal and Panthi, 2002).The (BFIA) Banks and Financial Institutions Act 2017, an umbrella act of financial legislation, governs the financial sector of Nepal. It has categorized financial institutions as class A, B, C, and D, depending on their minimum capital requirements. The Nepal Rastra Bank (NRB), the central bank, regulates and licenses financial institutions (NRB, 2020). In 2022 mid-May, the banking and financial institution to carry banking transaction in Nepal counts 127 comprising 27 Commercial Banks, 17 development bank, 17 finance companies and 65 micro finance institutions, and 1 infrastructure development bank. The NRB's comprehensive merger by laws 2011, has regulated to minimize the number of banks in Nepal to foster and make competitive banking system. Thus the number of regulated bank and financial institutions have decreased than previous record. The numbers of local level without branches of commercial banks have come down to 3 (MoF, 2021; NRB, 2022).

AGRICULTURE CREDIT AND SUPPORTING FINANCIAL POLICIES IN NEPAL

Priority sector and deprived sector:

The NRB has directed all the BFIs compulsory to invest in the priority sector which includes agriculture, energy, tourism and SMEs. The Unified Directive 2020 of NRB has directed the commercial bank to invest at least 11%, 13%, and 15% of total credit in 2020/21, 2021/22, and 2022/23 respectively for agriculture sector. Likewise, other BFIs are also instructed to invest in agriculture as priority sector (NRB, 2020).

Table 2. Priority sectors investment target, instructed by NRB Unified directive 2020

Priority	Institution	2020/21	2021/22	2022/23	2023/24
Agriculture	A	11%	13%	15%	-
Agriculture, (SME) energy and tourism	B	16%	17%	19%	20%
Agriculture, (SME) energy and tourism	C	11%	12%	14%	15%

Source: (NRB 2020)

Since 1991/92 NRB has directed the bank and financial institution to lend the deprived sector credit with the objective of uplifting the socio-economic status of poor deprived people of the society (Dhakal and Panthi, 2002). The deprive sectors include the socio-economically and marginally deprived population including female, small farmers, labors etc. The provision of lending this credit in micro credit form, the NRB directive 2020 has directed all the BFIs to lend at least 5% of total credit as deprived sector credit. Failure to comply such provision cause the BFIs to be penalized in monetary terms. For agriculture purpose farmers, farmers' groups, agricultural firms are given several amount of micro-credit for production, buying the agri-inputs, machineries, building cold storage, processing units, livestock, poultry production etc. The women, unemployed, youth, farmers, workers, youth returned from foreign job are mostly targeted for this credit to support them for investing in agriculture, and income generating activities (NRB, 2020). Likewise, the MFIs and cooperatives are also provided the wholesale loan from A, B and C BFIs with mandatory to invest in deprived sectors. In 2021 July, deprived sector loan disbursement stood 7 percent of total credit compared to the minimum regulatory requirement of 5 percent by the commercial banks, development banks, and finance companies (MoF, 2021).

Concessional loan:

The monetary policy 2021, NRB has made mandatory for commercial bank to lend concessional loan at least in 500 projects and 300 projects for development bank for a fiscal year. The "*Integrated Procedural for Interest subsidy on concessional loan-2075*" has been formulated for the implementation of concessional loan. Under this loan, up to 50 million of commercial agriculture and livestock loan, 5% of interest subsidy is provisioned and 2% for more than 50 million. Likewise, the provision of security like group security for less than 1 million, and business project security for more than 1 million has been made. The commercial agriculture and livestock loan includes different aspects of agriculture and livestock production, processing, storage of vegetable, fruits, medicinal plants, mushroom, eggs, dairy, meat, fish, poultry, livestock, beverages, spices, etc. Likewise, vegetable, seed, floriculture,

horticulture, livestock, processing in vegetable, meat, fruits production, seed, irrigation and irrigation equipment, agriculture machineries and equipment's, land development and conservation, forest and range land development and other agri-business are also included (MoF 2018, NRB 2021). A total of Rs.161.44 billion credit has been extended to 1, 04,109 borrowers as of mid-July 2021. Of which, Rs.106.98 billion has been extended to 46,057 borrowers for selected agriculture and livestock businesses (MoF, 2021). Likewise, larger portion of loan guarantee fees, insurance premium and interest were reimbursed by government as subsidies, through NRB, on regular repayment of loans. NRB has mandated BFIs to disburse minimum number of such loans on both branch wise as well as overall basis (MoF, 2018).

Financial access, literacy and financial inclusion in agriculture sector:

NRB has prepared four-year cycle (2020-2023) financial literacy framework targeting different profession including farmers. This frame work has aimed to outreach multi-stakeholders though NRB and other BFIs (NRB, 2020). Similarly, incentivizing on opening of branch in rural areas, launching open bank account campaign, easing operation of branchless banking, increasing focus on modernization of payment system are some recent measures to expand financial inclusion. The government has adopted policy of establishing at least one commercial bank branch in each local authority level. There are 753 local authorities where the commercial bank has reached to 750 local authorities. The government exempted Cash Reserve and Statutory Liquidity requirements for BFIs to extend their services in remote areas. BFIs are allowed to open one branch in Kathmandu valley only upon opening at least three branches outside Kathmandu valley, where at least two branches should be located in municipality or village level. Furthermore, to improve the financial access and banking service, BFIs are directed to open provincial offices. The commercial banks branches which are carrying out the government transactions of rural municipalities and municipalities are planned for establishing focal desk to promote additional credit in agriculture (MoF, 2021). Likewise, MFIs are allowed to open one branch in sub-metropolitan city only after opening one branch in the municipality and rural municipalities. The bank account opening campaign has made compulsory provision to have a bank account to receive social security allowance, expansion of branches, expansion of stock market with the increasing participation of large people, the access of Nepalese to bank. Around 68.97% of adult population (>15 years) have bank account, among them two third are active users. Likewise, there are many other organizations like USAID involved in increasing financial access to the farmer through new approach like branchless banking. Likewise, the priority sectors and deprived sectors in credit of NRB directives has played significant role in farmer's inclusion. The micro-credit has made the small and deprived farmer to enable them in small and micro entrepreneurship (NRB, 2020).

Financial Sector Development Strategy (2016/17 - 2020/21):

The financial sector development strategy has adopted the financial access and inclusion as pillar of banking system. It has emphasized on several techniques for increasing the financial outreach in rural and remote areas. The techniques for increasing the availability of BFIs services in rural and remote areas are focused with development of proper policies to expand the financial access and financial inclusion, and regulatory and supervisory framework for MFIs, institutional arrangement for broadening the financial access, public awareness through financial education; and consumer protection with respect to utilization of financial services and products. The financial access and inclusion includes the farmer and agriculture profession too (NRB 2020). Likewise, the Monetary policy 2021 has planned to formulate and implement the second Financial Sector Development Strategy and fourth Strategic Plan of the NRB for the sustainable and inclusive development of the financial sector and to enhance financial access (MoF, 2021).

Fifteenth five-year plan (2019/20- 2023/24):

The fifteenth periodic five-year plan has targeted to develop the annual average growth rate of agriculture by 5.5 percent until 2024. The 15th plan has specified poor credit expansion as major reason for poor development on agriculture. Some action plans are like encouraging the BFIs to expand loan in priority sector including agriculture, making necessary arrangement for concessional loan and refinancing, increasing the financial literacy, maximum utilization of information technology to expand access to financial services and products, encouragement of micro finance in remote and backward areas, expansion of financial services to all local authority levels through cooperatives and similar community-based institutions, promoting credit to farmers and women through various schemes, and strengthening of agriculture produce and livestock insurance are planned to increase financial access. Likewise, the cooperatives and private sectors are selected for collaboration to promote mechanization, expansion of agro-processing and other agro-industries, mobilization of concessional loan, expansion of credit and insurance services for production, processing, storage, and marketing of agricultural produce, involvement of cooperatives in the market system and enhancement of institutional capacity of cooperatives to ensure farmers' involvement in cooperatives (NPC, 2020).

Agriculture Development Strategy ADS (2015-2035):

The ADS 2015, proposed to increase the profitable commercialization, competition, mechanization, agribusiness, and export promotion with increasing the credit volume and number of financial products (inputs) to the farmers. ADS has prioritized credit access for increasing value of raw form of Nepalese market in export promotion and value addition program to increase the competitiveness of Nepalese product. The financial inclusion is highlighted for all farmers from all gender and socio-economic

status of all geographical regions to the means like land, inputs, credits, market, irrigation, technologies etc. Likewise, ADS has focused to implement secured *transaction act* to strengthen the contractual arrangement, future crop as collateral for farm credit and inputs, and also the development of hire-purchase or financial leasing for agriculture market promoting and improving financial access. The ADS has prioritized dealer financing system for providing financial services to agri-inputs dealers through commercial banks either by extending credit on commercial terms to dealers or from NRB "deprived sector" lending program (MoALD, 2015).

Promotion of Small loans:

The government has allowed to charge only up to 2 percentage points above the base rate of respective BFIs and no service charges or prepayment fees for the loans up to 1.5 million, in agriculture, business and enterprise. Likewise, for the small and medium enterprises, occupational agriculture and income generating activities in earthquake prone areas, BFIs can provide loans up to 2 million. On these kind of small loan, agricultural land without access to road can also be accepted as a collateral. Similarly, BFIs can provide loans up to 1.5 million for agriculture production like coffee, tea, oranges or livestock production or milk production, on the project evaluation, without any need for fixed assets as a collateral (NRB, 2020).

BFIS (BANK AND FINANCIAL INSTITUTIONS) OF NEPAL IN AGRICULTURE SECTORS

Flow of Credit and financial services in Nepalese agriculture

Table 3. Sector wise outstanding agriculture credit by different bank and financial institution (million rupees)

Year	A	B	C	Credit percentage
2011	14191.6	2578.0	1508.8	2.6%
2012	23407.3	3689.2	1697.6	3.6
2013	31531.3	6338.7	1913.8	4.16
2014	40270.1	8697.6	1942.1	4.5
2015	50706.2	12422.9	2030.6	4.7
2016	61125.1	15580.3	2086.1	4.6
2017	75349.9	11607.1	3084.2	4.5
2018	116435.9	15538.8	3781.8	5.6
2019	166038.3	22564.4	4854.7	6.6

2020	201758.4	19281.5	4732.5	6.9
2021*	-	-	-	7.6

Source: (MoF 2021, NRB 2021)

The economic survey of 2021 shows that, till march 2021, only 7.6% of credit was disbursed solely to agriculture (MoF 2021).The table 3 depicts increasing trend of agriculture credit flow, however the percentage of credit directed to disbursed by NRB was very low. The total credit flow in prioritized sector by commercial bank was 34.45% of total credit flow, comprising 13.2% in agriculture and 21.2% in off agriculture sectors. The BFIs investment as credit flow in the consumption was highest 70.5% of total credit. Despite of prioritization by government, the credit flow in agriculture was secondary comprising the value to NRs. 442 million. There is increment in agriculture investment, but still there is high credit flow for consumption, followed by agriculture (MoF, 2021).

BANKING AND FINANCIAL INSTITUTION IN AGRICULTURE CREDIT

Commercial Bank in agriculture Credit:

The credit flow of commercial bank has significant impact in agriculture production and AGDP. Their services in rural areas facilitate the agricultural production and directly stimulate agricultural growth (Rimal 2014). The commercial bank has provision of commercial agriculture and livestock loan facility, and other credit and saving facilities targeted for the farmers. By the 2023, the monetary policy of 2021 has made provision for commercial bank to invest at least 15% of their total credit in agriculture (MoF 2021). However, the agriculture growth from commercial bank seems very less noticeable. The commercial banks are more interested in manufacturing loan rather than the agricultural loan. In 2021, 7.8% of the total credit was disbursed in agriculture sector which was less than 11% directed by the NRB (NRB 2021).Beside of these, the priority of bank in 2021 was wholesale and retailers followed by service industries, production, and construction. The agriculture credit was in fourth rank (NRB, 2021).

Agricultural development Bank Nepal (ADBL):

ADBL is the foremost financial institution for providing micro-financial services in Nepal. It was first institution to initiate the group based micro credit program known as “Small Farmer Development Program (SFDP)” in 1975. The SFDP was implemented to increase the living standard and economic status of small farmers including the tenants and landless laborers (Dhakal and Panthi, 2002). Among the existing commercial bank of Nepal, ADBL is lead commercial bank to invest in agriculture. More than 30% of credit was invested by ADBL in agricultural sector. Several credit for livestock, poultry, cold storage, agriculture input, SMEs and other financial services like Kisan credit card and Kisan app are forwarded by the ADBL for the Nepalese

farmers to provide agricultural information along with financial resources (ADBL, 2021). The monitory policy 2021 has promoted ADBL as lead bank for agriculture credit. The ADBL is allowed to issue agricultural bond to ensure availability of long term financing in agriculture sector (NRB 2021).The ADBL connect with other institutions like MFIs and cooperatives to provide micro credit to small farmers and micro entrepreneurs (ADBL, 2021).

Micro- finance institutions (MFIs):

MFIs are the important financial institution to provide financial services to the rural and lower income families (MoLJPA 2017). To expand the MFIs and increase the financial access, NRB has made provision to extend the MFIs in those areas which are underserved by other types of banking institution (MoF 2021). MFIs provide micro-credit, small value non-collateralized loan to poor on the basis of group solidarity mechanisms. It targets the rural areas to provide the micro credit especially in (micro, small, medium enterprises) MSME. The interest rate of MFIs is very lower, the NRB has made provision of maximum interest rate cap of 15 percent. Likewise, the refinancing policy has been extended to MFIs that has made more possibilities on low cost of burrowing in micro-credit. However, the MFIs are also found charging higher interest rate of 18 to 24% due to higher operational cost which has made the rural livelihood unable to repay the loan (ILO 2019).

The study of (Oli, 2018) showed that increase in microenterprises loan and total assets leads to increase in GDP and Per Capita Income (PCI). Thus MFIs has significant role in increasing the economic growth of country. Likewise, micro finance has assisted in creation of employment through promoting the SME. It has become best option for financial inclusion including rural, poor, underserved, deprived, farmers, women etc. (NRB, 2020). The loan of MFIs are generally used for small enterprises, agriculture, livestock, poultry, and other income generating activities like manufacturing, carpeting etc. However, the rural communities prefer micro credit for consumption rather than agriculture, the priority of agriculture is behind in MFIs (Paudel 2013, ILO 2019). For more effective credit flow, credit utilization and enhance the micro finance outcome, some important factors like increase in loan size, effective means to identify poor and targeted people, basis follow up and monitoring and training are urgent needs in MFIs.

Cooperatives in agriculture sector:

The constitution of Nepal 2015, has declared the cooperatives sector as one of the three pillars of national economy. According to the department of cooperative, there are 29,886 cooperatives in Nepal out of which 79.5% of total cooperative represent as local level cooperative followed by 20% provincial cooperative and 0.5% of federal cooperative. Majority of cooperative represents the rural and local level of Nepal. Similarly, the major type of co-operatives operating in Nepal are saving and credit

cooperative (39%), followed by agriculture (32%), multipurpose (13%), dairy (5%), consumers (4%), and others like bee keeping, vegetables and fruits, tea, coffee, medicinal plants, sugarcane, sweet orange, electricity etc.(DeoC, 2018; DeoC, 2020). Cooperatives had played major role in poverty alleviation, socio-economic empowerment, skill and capital utilization, micro-enterprise development, promotion of consumer financial literacy (Khatiwada, 2014). The famers who are member of cooperatives has enjoyed higher production, accessibility to inputs, subsidy, technical information, and commercialization (Neupane, Adhikari *et al.*, 2015). However, the cooperative activities are focused more on savings and credit than on productive sectors and self-employment thus, the government has planned to make cooperative accessible, and expand the credit in productive and exportable goods (NPC, 2020).

CHALLENGES OF AGRICULTURE CREDIT AND FINANCIAL SERVICES IN NEPAL

Informal banking access:

The Nepalese population depending on formal banking sector account only 45 percent. This hesitation on formal sector is due to banking fees, long distance to bank, low financial literacy, cultural barrier etc. Nepalese farmers are found burrowing loan with higher interest rate from informal sectors like farmer group, women group, individual money lenders (neighbor, relatives etc.) or stores their cash at home (Gupta, Gautam *et al.*, 2016, WI 2021). Likewise, similar kind of financial products and services for both urban and rural areas, has made products and services unattractive for rural population. Thus BFIs should make their financial product and services attractive and understandable for rural population comprising the farmers.

Financial literacy and technology:

The study of Mishra, 2021 depicts that education in farmer's is important factor for accessing the agriculture credit. But there is lack of proper knowledge on banking services and products, lack of skills and attitude development to change this knowledge to behavior, awareness in availability and use of digital financial services etc. The rural areas farmers are unknown to different financial products like insurance, concessional loan, commercial agriculture and livestock loan, procedures, digital banking. They are depending on informal credit institution and rely on high interest loan. They are more vulnerable to the frauds and malpractices (Karn, 2018; NRB, 2020).

Still 31.9% of Nepalese have not access to bank account. The use of financial technology is increasing but in a limited percentage where technologies like internet banking, mobile banking and ATM user is only 3.86%, 32.03% and 20.35% (NRB, 2020; MoF, 2021). The rural population are unable to use and are not interested in technologies due to poor information technology knowledge's, language barriers, network problems etc. Thus these communities should be prioritized to increase their literacy that will enable them to invest rationally and make rational financial

decision. The technologies must be made in accordance to need and literacy level of farmers. The infrastructure should be developed for network and communication.

Poor physical infrastructures:

Most of rural and remote areas in Nepal relies in agriculture economy. Despite of commitment to reach to underserve areas and providing agriculture specific loan, BFIs are unable to approach to rural farmers due to network and technical issues. There are limited physical infrastructure and limited economic opportunities for these institutions to flourish in those areas. The operating cost will be high for them to reach out every rural part to reach farmers (Karn, 2018; WI, 2021).The rugged terrain, resource constraint on those areas challenge to develop basic infrastructures, information and communication technologies which is conducive for farmers. Furthermore, the farmers feel costly to reach BFIs due to long distances for them to travel. Thus, it is important to develop basic infrastructure like road, communication, electricity, irrigation, and transport in both agriculture and local economy. Extension of branchless banking system in those areas may assist the farmer to access financial services too.

Lack of assets for collateral:

The study of Mishra, 2021 found that farmers were reluctant to take agriculture credit due to lack of collateral with them. The government has made provision of collateral free, or acceptance of road less agriculture land (NRB, 2020). However, the Nepal Financial Inclusion Road Map reports that around 24% of Nepali adult were refused for loan due to lack of sufficient income and 19% were unable to provide the collateral. Practically for the creditworthiness of the clients, formal BFIs demand strong collateral and lot of mortgage and annual income of farmers (Bhatta, 2014). The agriculture land is less preferred due to poor marketability and low value. The BFIs feel risky to disburse the loan against the collateral of agricultural land (WI, 2021).

The approach like contract farming, future crop collateral, ware house financing should be implemented which has been already addressed in secured transaction act of Nepal. Implementation of scientific land categorization, and disbursement of loan on the basis of categorized land, can ease BFIs for providing loan to farmers.

Lack of Insurance:

The monsoon based farming, unsure availability of inputs, non-guaranteed market, sudden outbreak of disease and pest has made the Nepalese agriculture riskier and vulnerable. Thus insurance companies are reluctant to insure the crops and livestock due to higher risk, and it is difficulty in accessing the accurate risk, input cost and losses in crop production. Furthermore, the geographical and infrastructure constraints, lack of human resources in rural resources, insufficient axillary services

like technicians and weather station are other factors hindering the agriculture insurance. The farmers are also not interested in agriculture insurance due to lack of awareness and lack of public confidence toward insurance market (MEFIN, IBN *et al.*, 2020, Thapa 2021). Thus to intensify the agriculture insurance public awareness campaign should be increased in farming community.

Credit ceiling:

The subsidy loan in agriculture cooperatives is limited to 10 million. If ceiling would be increased then it would be helpful to establish the mega agriculture structure like cold storage, go-downs, purchase agriculture commodities etc. The government should prioritize macro credit through the cooperative and MFIs to the commercial farmers (NRB 2020; Thapa 2021). Likewise, the small famer to access the small loan need to register their firm or company. These farmers have poor knowledge about this, thus the famer must be treated as natural entity to provide small credit.

Policy Hurdles:

In 2020/21 the commercial bank was directed to invest at least 11% of total credit flow, however the outstanding credit flow in agriculture sector was only 7.6% (MoF, 2021). BFIs is not positive to invest in agriculture, It better pays penalty to the NRB rather than investing in agriculture. There are many policies related hurdle that has made BFIs reluctant to invest in agriculture.

Firstly, The NRB has directed to finance any business on the basis of working capital which is not possible for the agriculture. Estimation of working capital based on stock, receivable, payable in agriculture is not practical. Thus financing in agriculture must be different than other business, since its production cycle is different and complex than trading cycle. The financing in agriculture can be done on the base of cost of production of particular agriculture enterprise (NRB, 2020; Thapa 2021). Secondly the farmers in Nepal are of different type ranging from small farmers to commercial farmers. There is no segregation of credit depending upon the categories of farmers. Simplification of documentation and operational procedure should be prepared by concerned authorities (Government/NRB/BFIs and MFIs) that will enhance financial access and can burrow easily.

The credit for the perennial crops, farmer receives revenue after long period thus the grace period must be categorized according to the nature of crops too. Likewise, there is limited redemption facility in case of risky condition like natural calamities, diseases, pest, etc. Thus the redemption policy must be strengthened to facilitate and motivate the agribusiness.

The monitoring and timely supervision of BFIs should be carried by government to know whether the BFIs are lending the loan to appropriate farmers, either BFIs asking

corruption for lending credit, distributing the subsidized loan to actual farmers and real farmers, paper procedure, lending on required time etc. There are number of policies and regulations that are made for systematic financial system, but they are becoming hurdle for agriculture credit. Thus government should think about to relax these hurdle for farmers and agriculture purposes.

CONCLUSIONS

The poor credit expansion is the major reason for poor development on agriculture. Despite of government regulations, the BFIs are reluctant to invest in agriculture. The commercialization, mechanization, competitiveness, import substitution and export promotion is only possible if there is optimum investment in agriculture sector. The BFIs, cooperatives, MFIs and other registered financial institutions providing the financial services in Nepal are instructed by government to invest in agriculture as priority sector. However, the higher operational cost of BFIs branches, poor physical infrastructures, and some credit policies like credit ceiling, short grace period for perennial crops, group based and collateral free loan etc. has hurdled BFIs to invest in agriculture. The complex agriculture production cycle, high risk and un intensified agriculture insurance , subsistence farming, long paper procedure, demand of high value collateral are challenges for agriculture credit system. Similarly, the lack of financial awareness had made farmer unaware about subsidy loan, and other loan related facilities planned for them. Thus in order to increase the investment in agriculture both BFIs and farmers are needed to be motivated with some relaxation on credit policy, categorization of farmers according to credit volume demand, intensification of insurance, relaxation of credit ceiling for commercial farmer, warehouse financing, scientific land categorization for collateral and regular monitoring of BFIs either they are providing loan to the actual farmers or not. Likewise, the farmer friendly technologies, awareness campaign related with financial literacy, insurance, development of physical infrastructures, and branchless banking should be promoted to enhance the agriculture credit.

Agriculture is completely different enterprise than other trading and business. The biological cycle is completely different for different commodities. Hence the existing NRB directives and credit policies may not address the agriculture. To prioritize the agriculture and increase the agriculture credit, separate agriculture credit policies and agriculture credit directives should be prepared which will assist both farmers and BFIs in credit issues. Furthermore, there will not be conflict between agriculture and other enterprises regarding terms, conditions and other provisions of credit.

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HIGH ALTITUDE RANGELANDS INVASION BY NON-PALATABLE PLANT SPECIES IN THE PERCEPTION OF YAK HERDERS

S. R. Barsila[1]

ABSTRACT

The biological and socio-ecological dimensions of alpine rangelands degradation by invasive species have been considered in a field survey conducted in two yaks (Bos grunniens) rearing areas i.e., Langtang National Park (LNP) and Kanchanjunga Conservation Area (KCA). Data were collected by herder's interview using the well-prepared and pretested set of questionnaires (60), followed by a focus group discussion (FGD) and key informants survey (KIS) each five at each site by following a set of checklists. There was a common perception about the invasive species among the herders in the study sites. The Rumex nepalensis was the most invasive species reported (75% of the respondents) at altitudes up to 3000 m in the KCA, while it was additionally with Eupatorium adenophorum (60%) in the LNP, while the Lyonia and Juniperus were the common invasive species in both sites. Altogether, twelve plant species were reported as invasive and non-palatable species from various botanical groups were indifferent to the changes made by invasive species in rangelands soil characteristics but gave well insight into the declining productivity of grasslands and herbage productivity and quality. Herders established bush clearance and slash and burn agriculture in rangelands as traditional adaptation measures to control the invasive species. Mapping of risk zones of invasive and alien species in the alpine rangelands is necessary across the alpine rangelands of Nepal and a long-term monitoring framework is desirable to confirm the herder's information on invasive alpine species of Nepalese Himalayas.

Keywords: Adaptation, himalaya, invasive species, rangelands, yak

INTRODUCTION

The ecosystem provides several other alternative services (Dong *et al.*, 2007). Grazing is a major land-use system in the Hindu Kush Himalayan (HKH) region (Joshi *et al.*, 2013), as being vulnerable to a couple of natural and human-induced factors (Gentle and Thwaites, 2016). The rangelands in Nepal, are vulnerable to numerous anthropic stresses, together with over-grazing and over-exploitation of medicinal plants (Dong *et al.*, 2007). In addition, the looming impacts of climatic change in the subalpine and alpine regions of the Himalayas are omnipresent (Sharma and Tsering 2009), in conjunction with several notable issues at the ecosystems level (Gilani *et al.*,2017).

The climatic change would adversely impact the ecosystems and their economic potential and ecological property (Aryal *et al.*, 2013). The grasslands are one of the

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open areas for the invasion of alien species (Siwakoti *et al.*, 2016). The International Union of Conserve Nature IUCN has shown that there are over a hundred species that are probably to be shifted because of global climate change (Bellard *et al.*, 2013). Invasive plant species have the potential to considerably alter the ecosystem composition and functioning, drive native fauna to extinction (Hobbs, 2001), and the invasive plant species appear more dependent and influenced by anthropic disturbances (Bhattarai *et al.*,2014).

The invasive plant species richness has been reported correlated with phylogenesis factors (Acharya and Baral, 2017). Climate amendment threatens to shift vegetation, disrupting ecosystems and damaging human well-being. However, there is a scarcity of native abstraction information on vulnerability that hinders the management of natural resources like alpine rangelands from characteristic priority areas for adaptation measures to invasion. Nepal is a country ranked among the most vulnerable countries to biological invasions and climate change in the world (Shrestha *et al.*, 2019). The invasive plant species richness has been reported correlated with the anthropogenic factors (Acharya and Baral, 2017). There is a scarcity of native information on the management of natural resources like alpine rangelands in terms of invasion by non-preferable plant species. This study assumes the hypothesis that invasion is naturalized and coupled with livestock-induced vegetation shift due to high altitudes from the lower altitude over time in the Himalayan alpines.

METHODOLOGY

SITE SELECTION

Olang Chung Gola (Sherpa dominated) at the Kanchanjunga Conservation Area (KCA) of Taplejung district and the Gatlang (Tamang dominated) at Langtang National Park (LNP) of the Rasuwa of Nepal were purposively chosen for the study (Figure 1). The chosen sites have drawn the cultural diversities (Tamang communities in Gatlang (2500-3500 m) and Sherpas in the Kanchanjunga region(3000-4200) and variety in holding the domestic ungulates (i.e., yak, different yak & cattle hybrids, sheep and goats) rearing areas. The chosen sites were the model landscapes for different species of domestic animal holding and management systems i.e., transhumance where the livelihood of the herders is still predominant.

DATA COLLECTION

Data were collected through each primary and secondary literature survey. Within the literature survey, an in-depth review of the relevant journals was done in connection to the subject. A brief set of semi-structured forms was developed and pretested within the Langtang region. The set of the form consisted of the ecological aspects of the invasion in a very semi-structured format (60 households). The checklists

additionally consisted of the herder's ancient observed ecological knowledge on the native and invasive and non-palatable species and their rankings. The respondents were asked to produce a worth from 0-100 score from low to high rank. The checklists were separately developed for FGD (5 at each site) and the KIS (5 at each site) respectively.

Later in the FGD the 'sample display' methodology was followed. The locally available plant species (35) were shown to the normal herders and any incidents within the last 10 years within the goat and sheep, yaks, yak×cattle (*Urang Chauries*) and cattle×Yak (*Dimjo Chauries*) herds.

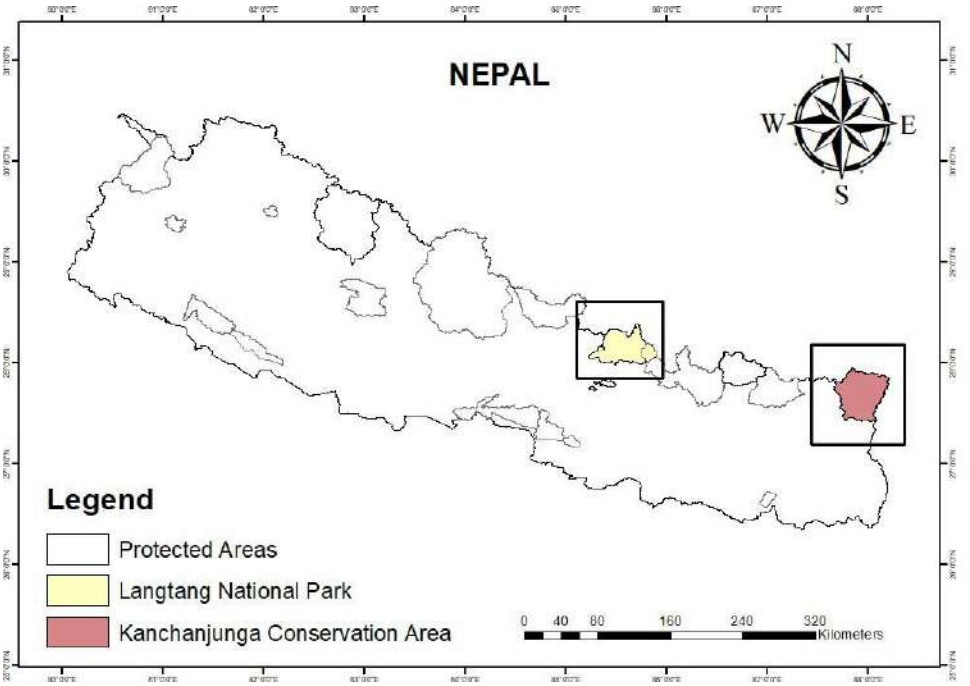

Figure 1. Map of Nepal showing two Protected Areas and the survey sites of the study namely Langtang National Park (LNP) and Kanchanjunga Conservation Area (KCA)

Later a transect walk was followed to grasp the sites of toxic plants, incidents while grazing etc. that range from 2500 m to 4800 m.asl. Later all information was verified through the key informant's interview at each site. A short questionnaires survey and checklists were used to collect the primary information that consisted of the information in three broad categories i.e., the pastoralism in the community, the herder's observations on alien species and their invasion potential of the native grasslands respectively.

Plant specimens were selected based on the observation of the native herders as the key informants. The specimen was collected and identified later with the required literature from the Fodder and Pasture Division of Nepal Agriculture Research Council (NARC), Khumaltar Nepal. The traditional healers in the Tamang communities and Sherpas *Amchis* (Tibetan traditional medicine practice) local healers (that include priests locally known as *Lamas*), plant traders, and experienced and old people (including herders) were selected as the respondents and two focus group discussion were conducted at each site. Permission for the interview was obtained verbally from every variety of respondents before the interview.

DATA ANALYSIS

The data were visualized thorough summary of the herders' responses and a chi-square test for the ecological aspects of invasion. The invasive non-palatable (un-grazed) species were shown in rank based on the herders' response to the grading (0-100) in the table.

RESULTS AND DISCUSSIONS

LIVESTOCK GRAZING SYSTEM

The herders within the survey sites managed the yaks and chauries (Urang and Dimjo chauries) and the majority of sheep within the transhumance followed by sedentary grazing (sheep and goat) and there have been nominal cases of the stall feeding (cattle) in the lower basins at each site. Later, it was found that both small and large ruminant domestic ungulates were the detrimental species for the native pasture species, whilst the invasive species were typically rumoured to be astringent for grazing species. Herders additionally responded to a declining trend of the native pasture species, and there have been hardly any animals grazing on the invasive forbs because of their astringent character (Table 1).

The invasive species were reported by the respondents as extremely prolific and propagated each by seed and also the vegetative propagules, such fact has been reported also by Cantero *et al* (2003) with lower palatability and smaller proportion of zoochory. Moreover, these species were adapted to dynamical ecological situations i.e., low and high light intensities. The native species were found responsive to a selected style of soil fertility however the invasive species were adapted to any soil fertility status. The grazing patches shaped throughout grazing were the first sites of invasion (Table 1).

The herders additionally responded to the high grazing pressure in the rangelands and grazing had induced the multiplication and site colonization might be attributed to the animal movement during transhumance along the altitudinal gradient. In the

herders' experience, the native species' grasses and sedges were more accompanied by coarseness than the invasive species, whilst the invasive species were thorny (e.g., *Berberis*) as shown in table 1.

The invasive species had been distinguished with a higher potential to migrate to elevations in comparison to the native species in the rangelands (Table 1, 2). The species richness was low in invasive species dominant patches, while it was found lower in the native grassland patches. Further, the invasive species were found to encroach even the water bodies (lakes) within the study area (mainly in the Langtang region) by *Acorus calamus*. The invasive species were further pointed out with higher potentiality to adapt to the climate and weather changes being due to poisonous or toxic plants (Table 2,3).

The indigenous knowledge is considered a base of the current knowledge system of herding communities that have evolved over generations (Berkes *et al*., 2000), and maintains approaches to land use that are appropriate to the varied biophysical conditions, and ethnical diversity that characterizes Nepal's mountain livelihood. The indigenous knowledge has additionally been employed in the management of natural resources (Schmink *et al*., 1992). Sustainable management of rangeland ecosystems has direct implications for the conservation of biological diversity and the livelihoods of local communities in general (Bhattarai and Upadhyay, 2013). The mechanisms that regulate operations would contribute to our knowledge of complex coupled human-natural systems (Dong *et al*., 2012), and the utmost of such knowledge is developed from the peoples' indigenous knowledge.

The farmers and herders in the Nepalese Himalayan landscape were already aware of many varieties of noxious flora and the traditional knowledge made an important contribution to ethnomedicine, and there is diversity in the use of plants as ethnomedicine across the landscape by ethnic groups (Bhattarai *et al*., 2006) with different medicinal properties (Taylor *et al*., 1996; Pokharel *et al*., 2008). To the knowledge of the author, this is the first report that the invasion exists in the Himalayan alpines of Nepal that integrates the herder's indigenous observation. In the former studies, it's been mentioned that the invasive species has been expected to shift towards high alpines in the years to come. Still, in the present study, it had been found that the herders had the traditional ecological knowledge on the invasion of the rangelands and there were already some non-palatable plant species naturalized in the alpine areas.

Table1. Summary of the herder's response to the native and invasive species and their habit in the rangelands of the Kanchanjunga (Olangchung Gola) and the Langtang region (Gatlang) of Nepal (data obtained by FGD and KIS).

Subsets	Grazable native species	Invasive species
Invasive vs native species	Naturalized and local	Species shifted from a lower altitude, naturalized shrubs, herbs and trees
Detrimental grazing animal species	Yaks and chauries, sheep	Animals do not graze on invasives
Changes in herbage composition	slow	rapid
Dominant species	native species are lost many	Increasing trend
Regeneration	Low and slow regeneration in native species	Highly prolific
Sensitivity to light stress	Adapted to a specific altitude and especially	Adapted to both low and high light intensities
Response to soil fertility	1 adapted to a particular kind of soil fertility	Adapted to any kind of soil even to the water bodies
Colonization	Natural distribution colonized over time	Colonized within a few couples of years.
Grazing effect	Resistant to grazing, poor biomass	Grazing induced the propagation and seed
Growth and development	Fibrous stems (grasses), short stature with more	Glossy and watery stems in many herbs (forbs), thorny and upright growth
Compatibility with native species	compatible but less aggressive	Compatible highly aggressive to dung
Odour and flavour	odour adapted by animals	The astringent flavours is not adapted by animals at
Soil properties	indifferent	indifferent

Source: Field survey, 2020.

Table 2. Invasion potential of the alien and invasive species in the high-altitude rangelands of the KCA and LNP (summary information gathered from FGD and KIS).

Assumptions	KCA	LNP
High altitude shift	Potential	Highly potential
Species composition	decreasing	Increasing and colonized
Animal poisoning	Adapted or tolerant/ resisted by domestic and wild	Sometimes lethal to domestic animals.
Invasion to special niche	Land invasion mostly	Invasion of land and water
Adaptation potential	Grazing intensity and species driven	Potential for high adaptation and naturalization

Source: Field survey, 2020.

It is an assumption that the cases of plant poisoning are much in the grassland-based systems presently where overstocking is predominant, and Nepal is already facing the problem of overstocking as seed dispersal could be expected more due to overstocking.In the present study, the majority of the respondents were confident about the positive effect of grazing on the invasion of grazing lands. The grazing animals act as the transporting agents (Belsky and Gelbard, 2000) to seeds of alien species by both endo- and epi-zoochory, trampling, and feeding and, the survival of invasive species is favoured by grazing avoidance (Vavra *et al.*, 2007). The changes in vegetation distribution that are altered by grazing may be a major reason for invasive species encroachment.

The patchiness in the rangelands can be considered as an example altered by the grazing. The habitat patchiness provides the space for the expansion of the invasive alien species (e.g., Harrison *et al.*, 2001). Temperate humid grasslands are known to be notably vulnerable to invasion by invasive plant species once when grazed by the domestic livestock (Hayes and Holl, 2003) Furthermore, Nepal's alpine rangelands are reported to be already overgrazed (Banjade and Paudel, 2008)) and facing socio-economic crises (Gentle and Thwaites, 2016; (Bhusal, *et al.*, 2018).

The herders positively responded to the effect of grazing pressure increased the invasion of alien and non-preferable species in the alpine rangelands. As grazing pressure increases, perennial grasses declines, while the relative proportion of forbs and annual grasses increases (McIntyre and Lavorel, 2001). In a continuously grazed and degraded pasture such vegetation trend has also been reported (Barsila, 2019). It is found that grazing promoted exotic plant invasions, and was confidently responded to by the herders in the present study, which might have elicited the functional heterogeneity of vegetation at the landscape scale (Chaneton *et al.*, 2002).

Herders responded to a high prolific behaviour of the invasive species in the present study, although, the trait-specific characteristics were difficult to identify in alarger scale in the survey. The scientific evidence suggests the traits specific biotic interactions became the foremost vital drivers of success or failure of the growth and development (Kempel *et al*., 2013), and generally, the alien species can propagate even in neglected and abandoned lands (Csontos *et al*., 2009) that has been well ascertained by the herders over time in the present study sites. The prolific amount of growth and reproduction in invasive plants as perceived by the herders is also achieved by greater net photosynthesis and/or resource-use efficiency (McDowell, 2002 & Ordonez and Olff, 2013), even at a higher level of disturbance (Pattison *et al*., 1998). The disturbance in the study sites has been created due to overgrazing or grazing elicited soil loss or erosion. In woody species, there is a tendency to adapt to the low light irradiance (Sanford, *et al*., 2003), such tendency is foreseen for the woody species such as *Eupatorium, Juniperus, Rhododendron, Berberis* etc. that were pointed out by the herders in the present study.

The astringency and thorns attributed by the invasive species might be a natural strategy for survival or grazing avoidance in the native species-dominated areas. These characteristics of such species have been perceived over time by the herders in the present study. An experiment in Hawaii conjointly proves that the greater odour emission capacity could confer protection against multiple stresses and may partly account for the success of the invasive species, will but invasive species additional competitive in response to new global change-driven combined stresses (Llusià *et al*., 2010). The different odour and flavour reported by respondents in the invasive species might be the grazing avoidance mechanism. Furthermore, the alien species had a higher efficiency in water transport (i.e., higher minimum leaf water potential and lower wood density values) and faster resource acquisition and use (higher specific leaf area values) than the native species (Zeballos *et al*., 2014) as compared to native species. There is a strong tendency for invasive species to possess larger stomata conductance than native species (Cavaleri and Sack, 2010). However, all the scientific mechanisms related to ecological invasion could not be dealt with poorly educated herders but could be dealt with in a better way in future biological studies.

ECOLOGICAL ASPECTS OF INVASION

In herders view, the *Rumex nepalensis* and the *Eupatorium adenophorum*, followed by the *Lyonia* and *Juniperus* respectively were the most invasive species in the rangelands.We did not find the problem of invasion of water bodies in KCA while it was reported threatened by *Acorus* in the Gatlang area of the LNP.

The livestock death rates were about 2-5% across the study sites and *Urang* and *Dimjo chauries* were more in the KCA and sheep in the LNP respectively. The distinction in

invasive species was additionally imperative to the altitude in the survey sites because it was up to higher altitudes in Kanchanjunga 3000-4000 m) than the Langtang region (2500- 3000 m) on an average. The herders were indifferent to the changes created by invasive species within the grazing land's soil properties.

In question to climatic change, the shift of native vegetation to higher altitudes was also responded well by the herders. The high-altitude shift of *Berberis* and *Rhododendron* in the Kanchenjunga and the *Juniperus* and Rhododendron *sp*. in Langtang was reported as the key species of indicator of climate change. The bush clearance and slash and burn agriculture practices were the predominant measures of bush management in the survey sites (Table 4 &5).

Table 3. Summary of the herder's response about the most detrimental invasive species in the high-altitude shift in the Kanchanjunga and the Langtang area of Nepal.

Attrubutes	KCA	LNP	Total	x^2 test			
	N=30	N=30	N=30	CC	Pearson x^2	LR	p-value
Rumex nepalensis	25(83.3)	20(66.7)	45 (75)	1.42	2.22	2.56	0.136
Eupatorium adenophorum	14(46.7)	26(86.7)	40 (66.7)	9.08	10.80	11.37	<0.01
Lyonia ovalifolium	21		21				
L. ovalifolium+ *Juniperus recurva*		21	21				
Livestock death	1.89(0.39)	5.3(0.89)	3.63 (1.78)				<0.001

*Values in parentheses indicated percentage. For livestock death rate values in parentheses indicate the standard deviation, CC represents Contingency Coefficient, LR represented the Likelihood Ratio. (*Source: Field Survey, 2020).

The common sensitive domestic ungulates due to climate change was responded to yaks and chauries, mountain goats and sheep respectively. The household holding of yak and chauries was bout 30-45 within the surveyed households. The goats (average 10 holdings) at low altitudes were recorded across the survey sites and sheep were mostly recorded in Langtang (27 holdings per household) as compared to KCA (5 holdings) respectively (Table 4).

Table 4. Herders' response to climate change sensitivity in livestock production and indigenous management of invasive species.

Attributes	KCA(N=30)	LNP(N=30)
Most sensitive livestock category		
Yaks and chauries	×	×
Goats	×	×
Sheep	× (10)	× (27)
Cattle	× (5)	× (7)
Most sensitive pasture sites	3000-4000 m	2500-3000 m
Management of invasive species		
Low altitude (<2000 m)	Bush clearance, slash and burn agriculture. Partial firing	
High altitude (2000-5000m)	Partial bush clearance	Partial bush clearance

× *indicated 99% positive response.*
Source: Field Survey, 2020.

HERDERS RANKING OF INVASIVE AND NON-PREFERABLE SPECIES

The ranking of the invasive and non-preferable species for grazing has been shown in Table 5, the species pointed out by the residents were site and altitude specific per the herder's ancient ecological knowledge. The species that were reported to be ubiquitous at both sites were *Rumex nepalensis, Lyonia ovalifolia, Rhododendron sp.* and *Ageratum sp.* respectively (Table 5).

Table 5. Ranking of major invasive species and their botanical groups in the survey sites and their availability at different elevations

Rank	species	Botanical groups	propagation	site	Altitude (m)
1	*Rumex nepalensis*	herb	seed	Both	2000-4000
2	*Eupatorium adenophorum*	herb	seed	LNP	2000-3000
3	*Lyonia ovalifolia*	shrub	seed	Both	2000-3500
4	*Juniperus sp.*	shrub	stolon	Both	3000-4000
5	*Berberis sp.*	shrub	seed	KCA	2500-3500
6	*Aconitum spicatum*	herb	stolon	Langtang	3000-4500
7	*Rhododendron sp.*	shrub	seed	Both	2000-4000

Rank	species	Botanical groups	propagation	site	Altitude (m)
8	*Ranunculus sp.*	herb	seed	KCA	2000-4000
9	*Alnus nepalensis*	tree	seed	KCA	1500-3000
10	*Acorus calamus*	herb	stolon	LNP	2000-3000
11	*Ageratum sp.*	herb	seed	Both	1500-2500
12	*Pterydium sp.*	fern	Seed, stolon	KCA	1500-2500

Source: Field survey, 2020.

The herders' response to vegetation change can be appreciated as indigenous knowledge well linked to scientific knowledge in the present study. There is a change in vegetation composition than the species richness in some areas (Vilà and Gimeno, 2007). In an exceedingly grazed rangelands in KCA, forbs were in the highest proportion followed by grasses and sedges (Barshila and Devkota, 2013). The changes in species composition are probable due to an increase in soil nitrogen (N) favoured by the invasive species (Vilà *et al.*, 2011). However, the amount of dung deposition was unknown in this regard.

Alien non-preferable and invasive plants are capable of modifying ecosystem functions (Gioria *et al.*, 2014), and this has been well reflected by the herders' response in the present survey. However, it is always not much justifiable to generalize the herder's response and literature findings, because impacts often appear to be both species- and site-specific (Scharfy *et al.*, 2009), or sometimes the impacts are heterogeneous and not unidirectional ((Vilà *et al.*, 2011). For example, the *Impatiens balfourii* in Europe brought from the Himalayas is believed to adapt to the high light intensities (Schmitz and Dericks, 2010) than in the Himalayas. Though not much clear in the present study it could be speculated that changes in soil properties are one of the strategies of invasive and alien species for adaption in addition to the herder's common perceptions. The invasive species alter the soil properties and affect ecosystem structure and biogeochemical cycles (Raizada *et al.*, 2008). There is a decrease in pH and increase of soil N in the invaded soil (Dassonville *et al.*, 2008) and a negative correlation exists between soil Ca-Mg content (Cantero *et al.*, 2003). Thus, the density of the invasive species (Truscott *et al.*, 2008) may decrease the dominance of native annual species and might induce the risks of fire (Brooks, 2003) possible due to higher above-ground biomass as compared to naturalized species. Such ecological information in the herders has been realized developed and undergone over generations as expected. However, the herders' educational status might have played the role in the perception of soil-related parameters. The luxurious growth of invasive species and species colonization under shade and dark soil in the invaded area has been well noted as responded by the respondents.

Nepal is currently under threat of temperature change owing to its ununiformed ecological and climatic transitions (Bhattacharjee *et al.*, 2017). Climate change is a driving factor when human interference in creating an area appropriate for the easy establishment of invasive species (Thapa and Maharjan, 2014). Invasive and alien species (IAPS) become the second-worst trouble to biological diversity (Baral *et al.*, 2014). Due to changing climate, some species have been projected to shift towards 4000 m within 2070 AD in Nepal (Thapa *et al.*, 2018). However, the invasive species reported in the present survey by herders were already acclimatized in the Himalayan alpines.The invasive alien plants in the lower basins are likely to be moved to higher elevations and are likely to invade fresh areas (Shrestha *et al.*, 2018). Some alien species can acclimatize to the increasing temperatures (Song, 2017).In Nepal, because of ecological diversity, such calculations have to be done in future studies. The long-term studies are desirable to see the correlation between the livestock losses and the occurrence of alien and non-preferable herbage species in the common grazing resources.

Examples of such economic losses due to the invasion of alien plant species embrace the loss of biodiversity; lowering of population densities for a good kind of taxa; disruption of ecosystem functions, together with nutrient cycling and succession; modification in community organization; and alteration in the physical characteristics of each terrestrial and aquatic habitats (Fleischner, 1994). Globalization facilitates the unfolding of invasive alien plant species (IAS) as international commerce develops new trade routes, markets and products merchandise (Meyerson and Mooney, 2007). The study sites are the well-known trade routes with the Chinese Tibet and the cross-border migration of invasive species at high altitudes could also be expected, but lacks such a measurement in the present study.

It has been reported in kinds of literature that the alien species cause major environmental harm in the US. These species are the cause of losses and altogether with control costs in livestock and human about 120 billion US dollars and posed risks to endangered species (Pimentel *et al.*, 2005). In Africa, current annual economic losses are from US$ 0.9 to 1.1 billion; near future losses are US$ 1.0 to 1.2 billion (Pratt*et al.*, 2017). The total annual loss caused by non-preferable and invasive species to agriculture and human health in Southeast Asia was estimated to be US$ 33.5 billion (Nghiem *et al.*,2013).

The long-term studies are desirable to see the correlation between the livestock losses and the occurrence of alien and non-preferable herbage species in the common grazing resources.

CONCLUSIONS

Using herder's indigenous knowledge on the invasion it had been found that the present management of alpine rangelands is largely neglected by the herding communities and lacks the institutional capacity for supporting the herding communities. The findings can be used well for future planning purposes. As a result, the livelihoods of the transhumance pastoralists can be promoted to cope with the climate and other social-ecological vulnerabilities. The study findings would be a key to selecting the sites of best rangelands renovation, as revealed from the herder's indigenous knowledge that the site and altitude would be the valuable basis for assessing invasion in the Nepalese Himalaya where the pastoral livelihood is still predominant. The site and the altitude have to be considered in the monitoring tool. The ecological prices of this nearly omnipresent variety of land use will be dramatic and will prevail in several units of the ecosystem. The uncontrolled mass grazing often facilitates the invasions; thus, the reseeding and rotational deferred grazing as management tools can be urged to prevent the invasive species in the Himalayan alpines. It would further be helpful to support the emerging policies and management practices in the alpine rangelands to support the grazing rights of transhumance pastoralists. It could additionally be recommended to incorporate the management of invasive alien species as a standpoint in reviewing current protected areas management policies that the pasture has an impact on livestock grazing. Likewise, the priority of areas of the parklands and conservation areas got to be shifted from an environmentalist role to ecosystem management to prevent the encroachment of the invasive alien plants in the future.

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EFFECT OF DETASSELING AND DEFOLIATION IN THE YIELD OF SWEETCORN IN KHOTANG DISTRICT OF NEPAL

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ABSTRACT

As maize is a C4 plant it is expected to have greater productivity however, its production and productivity are not found to its potential. Therefore, to evaluate the effect of detasseling and defoliation to increase the productivity, a field experiment was conducted on sweetcorn at Khotang, Nepal in 2021. The study was executed in Randomized Complete Block Design (RCBD) with three replications and seven treatments. The results revealed that number of kernels (608.46), number of rows (15.20), 1000 grains weight (210.68gm) were recorded significantly higher in the plot where 50% plants were detasselled. It clearly shows that 50% detasseling is one of the best options to enhance the yield of sweetcorn followed by detasseling + defoliation of all leaves leaving three leaves below the ear.

Keywords: Defoliation, detasseling, productivity, sweetcorn

INTRODUCTION

Maize is the second most important cereal crop of Nepal after rice which can be used as food, feed, fodder (Karki *et al.*, 2015). Maize (Zea mays L.) is a versatile crop with a higher adaptability range under diverse agro-climatic conditions and has the highest yield potential among the cereals (Yadav *et al.*, 2015). The area and production of maize in Nepal is 9,79,776 ha and 29,99,733 mt with the productivity of 3.06 in 2077/78. Nepal imports most of its Sweet corn frozen from India. Nepal is the largest importer of Sweet corn frozen and accounts 287 ton in the year 2020/21 (Volza grow global, 2020/21). The imports of sweet corn from India is increasing year by year due to changed food habit and tourism industry. So, the study regarding sweet corn would provide the policy feedback for future.

There are various types of maize each having distinctive characteristics and uses. Among all, sweetcorn is also the one which is prominent in worldwide context however it is barely cultivated and consumed in our country. It has a sugary rather than starchy endosperm and a creamy texture. The low starch level makes the kernel wrinkled rather than plumpy (Lahay *et al.*, 2019).

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Tassel represents the male flower whereas silk is the female. It is estimated that normal tassel of maize produces 2,50,00,000.00 pollen grains (Smith *et al.*, 2004), and utilize a huge amount of energy/nutrients. All the pollen grains produced by the plants will not be utilized for pollination. The nutrients used in producing pollens that are destined to be wasted can be diverted towards the sink of the plant by removing some tassels before pollen shed for better grain yield through accumulating the higher biomass and improved translocation of the accumulated biomass towards the sink (Jakhar *et al.*, 2017). Removal of 50% tassels at 3 DAE is highly effective in harnessing higher grain yield (Sammauria *et al.*, 2019).

Maize tassel removal helps light penetration in the canopy of maize plants that fulfils a high light requirement of the C4 plant like maize. Tassel removal increases both the seed yield and the seed quality of maize. Interaction of defoliation and tassel removal may also affect assimilate distribution between reproductive and vegetative organs (Heidari, 2013). Leaf removal and detasseling are important practices as they enable maize plants to maximize the allocation of total dry matter (TDM) to economic yield. Removal of the lower leaves at the anthesis-silking stage can potentially increase the maize yield since it reduces the apical dominance, increases photo synthetically active radiation intercepted, reducing resources competition and water loss by transpiration (Murindangabo *et al.*, 2019).

Increasing the yield per plant is the main motive of technical maize farming. Different cultural practices can be imposed or modified to increase the yields such as use of improved hybrid varieties, irrigation, and higher plant populations which are very hard task along with being too costly. Due to various lagging khotang district is not being able to progress in successive maize farming. The current production status of maize in Nepal is not able to sustain the consumption demand of people living in the country (Karki *et al.*, 2015). Still, here is dependency of traditional farming system, farmers are not aware about the potential benefits from the practice of detasseling and defoliation on maize farming. This system maximizes the intensity of the cob development by transferring the stored energy to cob development in growing period. Moreover, due to more demand of sweetcorn in the star hotels of Nepal, it is in higher demand range, which could give more return than any other varieties.

MATERIALS AND METHODS

EXPERIMENTAL SITE

The field experiment was conducted at Diktel Rupakot Majhuwagadhi Municipality of Khotang district, province-1 from February to July 2021. The research site is located at coordinates of 27.2193° N, 86.7919° E, and an altitude of 1540m. The soli texture was sandy loam to sandy clay. The daily maximum and minimum temperature varied from 15°C to 25°C and 17°C to 22°C, respectively during the cropping period.

EXPERIMENTAL DESIGN

The Randomized Complete Block Design (RCBD) was followed with three replications and a total of seven treatments. The unit plot size was 2*2.5 m^2, space between each plot was 50cm. The crop was planted with the spacing of row to row 60cm and plant to plant 20cm. There were 4 rows and a total of 40 plants in each plot. FYM was incorporated in the research field at the rate of 15t/ha two weeks before sowing. Similarly, chemical fertilizers were applied as per the recommendation i.e. 120:60:40 kg/ha of NPK, respectively. Half of the urea and full dose of other chemical fertilizers were applied as a basal. The remaining 50% of the total dose of the nitrogen was splitted into two halves and top-dressed during the knee-high stage and earthing up. Other intercultural operations such as weeding, irrigation, pest control measures were followed and performed uniformly in all the treatments.

Table 1. Treatment details

Treatment symbol	Treatment details
T_1	Control
T_2	Detasseling only
T_3	Detasseling + defoliation of 2 upper leaves
T_4	Detasseling + defoliation of 3 upper leaves
T_5	Detasseling + defoliation of all leaves below the third leaf below the ear
T_6	Detasseling + defoliation of 2 upper leaves and all leaves below the third leaf below the ear
T_7	Detasseling + defoliation of 3 upper leaves and all leaves below the third leaf below the ear

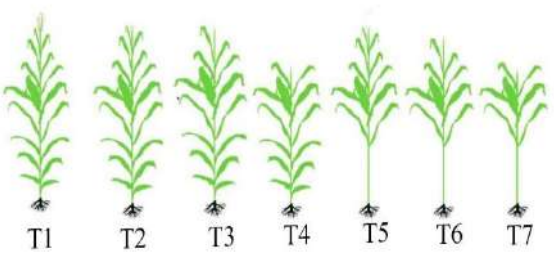

Figure 1. Detail of treatments

Detasseling was performed after 3 days of the emergence of the tassel on 50% per plot with respective treatments (Sammauria *et al.*, 2019). Defoliation was done after 3 days of the emergence of silk (Sammauria *et al.*, 2019). Pollen shed usually lasts for 5 to 8 days with peak shed by the 3rd day.

PARAMETERS RECORDED

Data collection and analysis

Vegetative, floral and metrical data measurements were taken from each plot, 5 sample plants were selected randomly and data were recorded. Floral measurements included days to 50% tasselling and days to 50% silking (Maydis formation) to calculate the effective days for tassel removal and ear development. Number of kernel rows per ear, total number of kernels per ear, fresh weight of ear (gm), weight of ear after removing cover(gm), weight of ear before removing cover(gm), weight of grain (gm), ear length (cm), ear girth (cm), cob weight (gm) were measured under the metrical measurements.

Whereas, weight of grain (gm) is concerned; sweetcorn is harvested in the immature milking stage when detachment of grain for weighing is difficult so, grain weight is calculated by subtracting the cob weight from the weight of the ear after DE husking.

The data were analyzed using Duncan's Multiple Range Test (DMRT) at 5% level of significance for the separation of means using the package agricolae. The collected data were entered into MS-excel version 2016 (compatibility mode) and were analyzed using R studio version 3.5.3.

RESULTS AND DISCUSSIONS

EFFECT ON DEVELOPMENT OF NUMBER OF KERNELS

Analysis of variance revealed that the number of kernels is significantly ($p<0.05$) influenced (Table 2) by detasselling and defoliation. The highest number of Kernels was recorded on T2, detasseling performed (608.46) which was significantly ($p<0.05$) higher than other treatments. The lowest number of kernels was recorded for T_7, detasseling plus defoliation of three upper leaves and all leaves below the third leaf below the ear (416.40) which is statistically similar to T_6, detasseling plus defoliation of two upper leaves, and all leaves below the third leaf below the ear (417.73), T_4, detasseling plus defoliation of three upper leaves (465.40) and T_1, control (448.68) respectively.

EFFECT ON NUMBER OF KERNEL ROWS

Analysis of variance showed that the number of kernel rows is significantly ($p<0.05$) influenced (Table 2). The highest number of kernel rows was recorded on T_2, detasseling (15.20) which was significantly ($p<0.05$) higher than any other treatments. The Lowest number of kernel rows was recorded at T_7, detasseling plus defoliation of three upper leaves and all leaves below the third leaf below the ear (13.60).

EFFECT ON WEIGHT OF GRAIN

Analysis of variance indicated that the weight of kernels was significantly ($p<0.05$) influenced (Table 2). The highest weight of the grain was recorded at T_2, detasseling (210.68 gm) which was significantly ($p<0.05$) higher than other treatments but statistically similar with treatment T_5, detasseling plus defoliation of all leaves below the third leaf below the ear (176.94 gm). The lowest weight of kernel was recorded for T_7, detasseling plus defoliation of three upper leaves and all leaves below the third leaf below the ear (125.85 gm) which was statistically similar with T_6, T_4, T_3, and T_1.

EAR WEIGHT BEFORE AND AFTER DEHUSKING

The analyzed data revealed that the weight of the ear after DE husking was significantly influenced and the weight of the ear before DE husking is not significantly ($p<0.05$) influenced.

Before dehusking, the highest weight of the ear was recorded on treatment T_2, detasseling (395.67 gm) and lowest weight of the ear was recorded on treatment T_7, detasseling + defoliation of three upper leaves and all leaves below the third leaf below the ear (289.66 gm).

After dehusking, the highest weight of the ear was recorded on treatment T_2, detasseling (275.00 gm) which differed significantly ($p<0.05$) from other treatments but was statistically similar with treatment T_5, detasseling + defoliation of all leaves below the third leaf below the ear (233.33 gm). The lowest weight of the ear was recorded on the treatment T_7, detasseling + defoliation of three upper leaves and all leaves below the third leaf below the ear (182. 67 gm) which is statistically at par with treatment T_1, T_3, T_4, and T_6, respectively (Table 2).

Table 2. Effect of detasseling and defoliation on the yield attributing traits of sweetcorn

Treatment	Number of kernels	Number of rows	1000 grain weight (gm)	Ear weight before dehusking (gm)	Ear weight after dehusking (gm)
1	448.867^{cd}	13.733^{b}	134.652^{bc}	302.333^{b}	194.667^{a}
2	608.467^{a}	15.200^{a}	210.679^{a}	395.667^{a}	275.000^{bc}
3	488.400^{bc}	13.733^{b}	162.394^{bc}	331.667^{ab}	219.000^{bc}
4	465.400^{bcd}	13.867^{b}	166.128^{bc}	327.333^{b}	219.667^{bc}
5	517.267^{b}	14.000^{b}	176.939^{ab}	357.333^{ab}	233.333^{ab}
6	471.733^{bcd}	13.733^{b}	153.009^{bc}	306.333^{b}	209.667^{bc}
7	416.400^{d}	13.600^{b}	125.854^{c}	289.667^{b}	182.667^{c}
LSD (0.05)	60.05255	0.4252501	38.98472	68.04504	41.83623
S. Em(±)	7.37	0.05	4.78	8.35	5.13
F-probability	<0.001	<0.001	<0.01	ns	<0.01
CV (%)	6.916232	1.709753	13.57914	11.58899	10.73127
Grand Mean	488.0762	13.98095	161.3793	330.0476	219.1429

Note: The common letter(s) within the column indicate non-significant difference based on the Duncan multiple range tests (DMRT) at a 0.05 level of significance, ** significant at 1% level of significance, *** significant at 0.1% level of significance. (SEm – Standard Error of mean, CV – Coefficient of Variation, LSD – Least Significance Difference)

EFFECT ON EAR GIRTH DEVELOPMENT

Analysis of variance proved that ear girth is not significantly ($p<0.05$) influenced (Table 3) by the operations carried out.

EFFECT ON EAR LENGTH

Analysis of variance revealed that the ear length is not significantly ($p<0.05$) influenced (Table 3).

EFFECT ON COB WEIGHT DEVELOPMENT

Analysis of variance revealed that cob weight (Table 3) was significantly ($p<0.05$) influenced. The highest cob weight was recorded for treatment T_2, detasseling (64.32 gm) which was significantly higher than other treatments but statistically similar with treatment T_1, Control (60.01 gm). The lowest cob weight was recorded for treatment T_4, detasseling + defoliation of three upper leaves (53.54 gm) which was statistically similar (at par) with T_3, T_5, T_6, and T_7.

EFFECT ON COB GIRTH DEVELOPMENT

Analysis of variance revealed that cob girth (Table 3) is not significantly ($p<0.05$) influenced.

EFFECT ON COB LENGTH

Analysis of variance revealed that cob length is not significantly ($p<0.05$) influenced (Table 3).

Table 3. Effect of detasseling and defoliation on the yield attributing characteristics of sweetcorn

Treatments	Ear length (cm)	Ear girth (cm)	Cob weight (gm)	Cob girth (cm)	Cob length (cm)
T1	14.58	13.95	60.01 ^{ab}	8.71	17.00
T2	16.57	15.66	64.32 ^{a}	9.85	17.93
T3	15.63	14.83	56.61^{bc}	9.49	17.75
T4	15.12	15.12	53.54^{c}	9.65	17.88
T5	16.05	14.98	56.39 ^{bc}	9.28	18.25
T6	14.85	14.71	56.66 ^{bc}	8.87	17.13
T7	13.95	14.12	56.81^{bc}	8.66	16.72
LSD (0.05)	2.19	1.09	4.79**	0.94	1.73
S. Em (±)	0.27	0.13	0.59	0.12	0.21
F-probability	ns	ns	<0.01	ns	ns
CV (%)	8.07	4.16	4.66	5.72	5.56
Grand Mean	15.25	14.77	57.76	9.22	17.52

Note: The common letter(s) within the column indicate non-significant difference based on Duncan Multiple Range Test (DMRT) at 0.05 level of significance, ** significant at 1% level of significance, *** significant at 0.1% level of significance. (SEm – Standard Error of mean, CV – Coefficient of Variation, LSD – Least Significance Difference.

COST BENEFIT ANALYSIS

Though detasseling is labour intensive, the b/c ratio would not be decreased but increased due to change in productivity. The b/c ratio of maize farming was found 1.4 in the case of improved irrigated condition (MRSMP, 2017/18). In case of detasseling, the labour cost would increase by just 2-3% in the section of labour. The productivity of detasseled maize would increase by 15% in total. So, the practice of detasseling is important and economically beneficial.

CONCLUSIONS

As the yield parameters like the number of kernels, the number of kernel rows per ear, weight of grains was found significantly higher in T_2 (50% detasseling) compared to other remaining treatments; detasseling can be recommended to increase the grain yield of the sweetcorn. Similarly, detasseling + defoliation of all leaves below the third leaf below the ear showed remarkable results after the detasseling only, with a second higher grain yield. On the contrary, Detasseling + defoliation of three upper leaves and all leaves below the third leaf below the ear appeared to have lower grain yield followed by control. Hence, we can conclude that 50% detasseling is the best way to enhance the grain yield of the sweetcorn.

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EVALUATION OF DIFFERENT GRAFTING METHODS IN PROMISING KIWIFRUIT VARIETIES AT LUMLE, KASKI, NEPAL

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ABSTRACT

Kiwifruit is usually propagated by grafting and cutting. Suitable method of grafting in Kiwifruit should be identified to elaborate the commercial production. To evaluate the success rate of scion varieties with different grafting methods in Kiwifruit a study was conducted for two consecutive years 2018 and 2019 at Lumle, Kaski. Five different varieties of Kiwifruit as scion (Allison, Bruno, Hayward Oblong, Hayward Oval and Monty) and three different grafting methods (tongue, veneer and wedge) were used to identify successful method of grafting in Kiwifruit. Grafting was done on January 1st and 2nd in both years. In the first year, shoot length was recorded highest in Hayward Oblong with veneer grafting (96.10cm) whereas shoot diameter was obtained highest in Monty with wedge grafting (6.61mm). Similarly in the second year shoot length was recorded highest in Hayward Oblong with veneer grafting (97.10 cm) and shoot diameter was observed highest in Monty with wedge grafting (6.71mm). In both years, the highest (100%) graft success was recorded in Allison with wedge grafting.

Keywords: Allison, grafting, kiwifruit, wedge method

INTRODUCTION

Kiwifruit (*Actinidia spp.*) belonging to family Actinidiaceae has spread from China to the other parts of world rapidly (Abedini, 2004). There are about 66 species of Kiwifruit in the world and among them about 62 species are found in China (Wang and Zhang, 1994). *Actinidia deliciosa, A. chinensis, A. arguta* and *A. eriantha* are the four species with high economic value (Honghua *et al.*, 2017). Commercial cultivation of Kiwifruit has gaining worldwide popularity because of its wider climatic adaptability, delicious fruits, precocity, high nutritive and medicinal values and high economic return (Zhengyi *et al.*, 2007). Allison and Hayward Oblong are promising variety in terms of its quantitative parameters (Khanal *et al.*, 2021). It is considered as one of the best fruit due to its high nutritive value, especially vitamin C as compared to other fruits. Along with vitamin C, it has high amount of carbohydrates, proteins and minerals. Kiwifruit is basically consumed as fresh. Besides, it is used in fruit salads, jams, marmalades, cakes as well as in the juice industry too. In Nepal, Kiwifruit is being cultivated in 2116 hectare where productive area is 1167 hectare with production of 4254 mt and yield of 3.65 mt/ha (MoALD, 2021). Due to high capital investment for vines, trellises and a permanent irrigation system production of

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Kiwifruit is expensive. It takes about three to four years for commercial fruit production. In Nepal there is huge potentiality for high quality Kiwifruit production, but it left far behind because of market and lack of awareness and research on this crop. Therefore, there is ample opportunity in Nepal to increase commercial production of Kiwifruit for local as well as international export (Gotame *et al*., 2016).

Kiwifruit is cash crop and it's demand is increasing globally; it helps to improve the economic condition of Kiwifruit growers and nurserymen. Despite the increasing demand of the quality planting materials for the commercial production, farmers usually face the problem of low graft success with huge loss. Occurrence of graft incompatibility due to improper grafting method and unsuitable varietal selection might be the reason for graft failure. Kiwifruit plants are usually propagated by grafting scion varieties onto seedling rootstock or by rooting Kiwifruit cuttings. Grafting is a common method for propagation but its success rate depends on both the rootstock and grafting type (Sedaghathoor and Noie, 2016). They may also be propagated by seed, but the resulting plants are not guaranteed to be true to the parent plants. Identification of appropriate vegetative propagation technique is mandatory in order to reduce the gestation period, increase productivity and ensure uniform product quality. The practice of grafting using desirable scion cultivars upon suitable rootstock will offer good opportunities for the perpetuation of good cultivars and utilization of advantage of rootstock resistant to abiotic and biotic stresses. The objective of this experiment was to identify the appropriate scion variety for the wild rootstock along with method of grafting in order to elaborate the commercial production of Kiwifruit in mid hills of Nepal.

METHODOLOGY

This study on different grafting techniques in Kiwifruit was done for two consecutive years 2018 and 2019 at Directorate of Agricultural Research (DoAR), Lumle, Kaski, Nepal. Two factors; Factor A: Five different varieties of Kiwifruit as scion (Allison, Bruno, Hayward Oblong, Hayward Oval and Monty) and Factor B: three different grafting methods (tongue, veneer and wedge) were used to determine successful method of grafting in Kiwifruit. One year old seedlings of wild Kiwifruit (*Actinidia callosa*) were used as rootstock for all scion varieties. One year old terminal shoots ranging from 0.6 to 0.8 cm in diameter and 10 cm in length having 2 buds each were collected from the Kiwifruit orchard of Lumle, Kaski, Nepal. Grafting was performed on January 1st and 2nd in both year 2018 and 2019. After grafting, the grafted seedlings were placed in media prepared from the mixture of forest soil and sand. The grafts were placed under temporary callus house having restricted light and regulated temperature to enhance callus initiation and reduce grafting failure. De-suckering was regularly carried out to remove the unwanted sucker's growth from rootstock. Observations were recorded regarding the number of suckers per plant, graft union height, graft union diameter, shoot length, shoot diameter, rootstock

diameter, number of leaves and graft success percent. The data were entered using MS-Excel and analyzed through R-Studio for ANOVA. The least significant difference (LSD) was determined at 5% level of significance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSIONS

EFFECTS OF VARIETY ON DIFFERENT PARAMETERS

During the first year of experiment, analysis of variance showed significant differences in three parameters viz; number of sucker/plant, graft union diameter (mm) and number of leaves among the tested varieties (Table 1). The number of sucker/plant was recorded maximum in Bruno and minimum in Hayward Oval (5.92 and 3.40 respectively). Graft union height ranged from 1.89cm in Hayward Oval to 2.20cm in Allison with insignificant difference. On the other hand, graft union diameter showed significant difference with the highest value with Monty (7.83 mm) followed by Allison (7.72 mm). Number of leaves was recorded maximum in Allison (8.46) followed by Hayward Oval (7.13). Graft success ranged from 57.33% in Hayward Oblong to 84.00 % in Hayward Oval (Table 1).

Similarly in the second year, analysis of variance showed significant differences in case of scion variety in four different parameters viz; number of sucker per plant, graft union diameter (mm), rootstock diameter (mm) and no. of leaves. The number of sucker/plant was recorded maximum in Bruno and minimum in Hayward Oval (6.12 and 3.60 respectively). The varieties were insignificantly different in graft union height with the value ranged from 2.09 cm in Hayward Oval to 2.40 cm in Allison. Graft union diameter showed significant difference among the variety with the maximum diameter in Monty (8.03 mm) followed by Allison (7.92 mm). Rootstock diameter was significantly higher in Allison (6.67 mm). Number of leaves was recorded maximum in Allison variety (8.66) followed by Hayward Oval variety (6.30). Graft success (%) ranged from 66.67 in Hayward Oblong to 84.00 in Hayward Oval (Table 2).

EFFECTS OF GRAFTING METHOD ON DIFFERENT PARAMETERS

The result from the first year of experiment showed significant differences in two parameters viz; graft union height (cm) and graft success (%) among the grafting methods (Table1). Grafting method did not show significant effect on number of sucker/ plant, graft union diameter, shoot length, shoot diameter, rootstock diameter and number of leaves. Graft union height significantly differed with grafting methods which had the highest value in tongue grafting (2.53 cm) followed by veneer grafting (2.10 cm). Final sprouting was also recorded maximum in tongue grafting (84%) followed by 82.4% in wedge grafting (Table 1).

Table 1. Performance of scion varieties under different grafting methods in Kiwifruit, Lumle, Kaski, 2018

Treatments	No. of sucker/ plant	Graft union height (cm)	Graft union diameter (mm)	Shoot length (cm)	Shoot diameter (mm)	Rootstock diameter (mm)	No. of leaves	Graft success (%)
Scion Variety								
Allison	4.68	2.20	7.72	66.46	5.64	6.57	8.46	73.33
Bruno	5.92	2.14	5.95	45.88	5.63	5.93	6.19	64.00
Hayward Oblong	4.19	2.02	6.75	75.42	5.54	6.06	6.10	57.33
Hayward Oval	3.40	1.89	7.10	57.80	5.79	8.00	7.13	84.00
Monty	5.11	1.95	7.83	52.59	5.91	6.44	6.89	72.00
Mean	4.66	2.04	7.07	59.63	5.70	6.60	6.95	70.13
CV (%)	32.47	32.41	20.15	53.77	14.03	48.27	30.23	40.54
P value	0.00	0.66	0.001	0.10	0.73	0.40	0.02	0.12
LSD (0.05)	1.10	NS	1.03	NS	NS	NS	1.53	NS
Grafting method								
Tongue	4.70	2.53	6.87	67.59	5.80	7.29	7.38	84.00
Veneer	4.54	2.10	7.11	53.38	5.42	6.30	6.58	44.00
Wedge	4.74	1.49	7.24	57.91	5.90	6.22	6.90	82.40
Mean	4.66	2.04	7.07	59.63	5.70	6.60	6.95	70.13
CV (%)	36.97	24.61	22.10	54.98	13.53	48.36	31.97	32.35
P value	0.91	0.00	0.69	0.29	0.07	0.42	0.44	0.00
LSD (0.05)	NS	0.28	NS	NS	NS	NS	NS	12.79
Variety*Grafting method								
Allison tongue	4.32	3.34	7.39	74.93	5.93	6.76	9.73	92
Allison veneer	3.52	1.88	7.97	32.60	5.02	6.33	6.12	28
Allison wedge	6.20	1.39	7.80	91.83	5.97	6.62	9.53	100
Bruno tongue	5.32	2.50	7.10	50.66	6.20	6.22	7.06	80
Bruno veneer	6.32	2.46	3.54	51.00	5.04	5.74	6.00	40
Bruno wedge	6.12	1.46	7.20	35.96	5.64	5.82	5.50	72
Hayward Oblong tongue	3.24	2.36	6.90	93.70	5.82	6.07	6.60	76
Hyward Oblong veneer	4.84	1.94	7.28	96.10	5.33	6.41	7.10	20
Hayward Oblong wedge	4.48	1.76	6.07	36.46	5.46	5.70	4.60	76
Hayward Oval tongue	4.84	2.18	6.26	56.90	5.24	11.23	6.36	92
Hayward Oval veneer	2.00	2.00	8.48	48.10	6.35	6.70	7.50	76
Hayward Oval wedge	3.36	1.48	6.55	68.40	5.78	6.06	7.53	84
Monty tongue	5.76	2.26	6.67	61.76	5.77	6.15	7.13	80

Treatments	No. of sucker/ plant	Graft union height (cm)	Graft union diameter (mm)	Shoot length (cm)	Shoot diameter (mm)	Rootstock diameter (mm)	No. of leaves	Graft success (%)
Monty veneer	6.04	2.20	8.25	39.10	5.33	6.29	6.20	56
Monty wedge	3.52	1.38	8.57	56.90	6.61	6.88	7.33	80
Mean	4.66	2.04	7.07	59.63	5.70	6.60	6.95	70.13
CV (%)	26.60	22.05	15.17	47.46	12.51	48.98	28.54	28.23
P value	0.00	0.00	0.00	0.00	0.01	0.61	0.05	0.02
LSD (0.05)	1.56	0.56	1.35	35.80	0.90	NS	NS	25.04

During the second year, significant differences were observed in two parameters viz; graft union height (cm) and graft success (%) among the grafting methods. Grafting method showed insignificant effect on number of sucker/plant with minimum in veneer grafting (4.74) and maximum in wedge grafting (4.94). Graft union height showed significant difference between the different grafting methods. The maximum height was measured in tongue grafting (2.73 cm) followed by wedge grafting (1.69 cm). Graft success was also recorded maximum in tongue grafting (88%) followed by 84.80 % in wedge grafting method (Table2).

INTERACTION EFFECTS AMONG VARIETY AND GRAFTING METHOD ON DIFFERENT PARAMETERS

In the first year, significant difference was recorded in case of interaction of scion variety and grafting method in six different parameters viz; final sprouting (%),number of sucker/plant, graft union height (cm), graft union diameter (mm), shoot length (cm), shoot diameter (mm) and graft success (%) (Table1). The number of sucker per plant was recorded maximum in Bruno scion variety grafted in veneer method (6.32) while graft union height was observed as highest with Allison variety grafted using tongue method (3.34cm). Likewise, the graft union diameter was recorded as highest in Monty scion variety grafted in wedge method (8.573mm). Shoot length was measured longest in Hayward Oblong variety grafted using veneer method (96.10 cm) whereas shoot diameter was measured shortest in Monty variety grafted by wedge method (6.616 mm). Rootstock diameter and number of leaves per graft did not show significant difference but the highest value was recorded in Hayward Oval variety grafted with tongue method and Allison variety grafted using tongue method (11.238 mm and 9.734 respectively). Graft success was maximum in Allison variety grafted using wedge method i.e. 100 % (Table 1).

In the second year, significant differences was recorded in case of interaction of scion variety and grafting method in seven different parameters viz; number of sucker/plant, graft union height (cm), graft union diameter (mm), shoot length (cm), shoot diameter (mm), rootstock diameter (mm) and number of leaves. The number

of sucker per plant was recorded maximum in Bruno variety grafted using veneer method (6.52). Likewise, graft union height was observed highest in Allison variety grafted using tongue method (3.54cm) and graft union diameter was recorded as highest in Monty variety grafted using wedge method (8.77mm). Shoot length was measured longest in Hayward Oblong grafted by veneer method (97.10 cm) whereas shoot diameter was recorded highest in Monty variety grafted using wedge method (6.71 mm). Maximum rootstock diameter was observed in Monty variety grafted using wedge method (6.98 mm) and maximum number of leaves per graft (9.93) was in Allison variety grafted using tongue method. Graft success was maximum in Allison variety grafted using wedge method i.e. 100 % (Table 2).

Table 2. Performance of scion varieties under different grafting methods in Kiwifruit, Lumle, Kaski, 2019

Treatments	Avg. no of sucker/ plant	Graft union height (cm)	Graft union diameter (mm)	Shoot length (cm)	Shoot diameter (mm)	Rootstock diameter (mm)	No. of leaves	Graft success (%)
Scion Variety								
Allison	4.88	2.40	7.92	67.46	5.81	6.67	8.66	80.00
Bruno	6.12	2.34	6.15	46.88	5.73	6.03	6.39	77.33
Hayward Oblong	4.39	2.22	6.95	76.42	5.64	6.16	6.30	66.67
Hayward Oval	3.60	2.09	7.30	58.80	5.89	6.30	7.33	84.00
Monty	5.31	2.15	8.03	53.59	6.07	6.54	7.09	78.67
Mean	4.86	2.24	7.27	60.63	5.83	6.34	7.15	77.33
CV (%)	30.29	31.49	19.91	51.67	13.12	9.62	27.93	27.72
P value	0.00	0.71	0.00	0.09	0.59	0.03	0.01	0.25
LSD (0.05)	1.07	NS	1.05	NS	NS	0.44	1.45	NS
Grafting method								
Tongue	4.90	2.73	7.07	68.59	5.94	6.31	7.58	88.00
Veneer	4.74	2.30	7.31	54.38	5.56	6.40	6.78	59.20
Wedge	4.94	1.69	7.44	58.91	6.00	6.32	7.10	84.80
Mean	4.86	2.24	7.27	60.63	5.83	6.34	7.15	77.33
CV (%)	34.73	24.88	21.77	52.92	12.75	10.20	29.74	22.71
P value	0.91	0.00	0.69	0.28	0.08	0.87	0.41	0.00
LSD (0.05)	NS	0.31	NS	NS	NS	NS	NS	9.90
Variety*Grafting method								
Allison tongue	4.52	3.54	7.59	75.93	6.03	6.86	9.93	92
Allison veneer	3.72	2.08	8.17	33.60	5.32	6.43	6.32	48
Allison wedge	6.40	1.59	8.00	92.83	6.07	6.72	9.73	100
Bruno	5.52	2.70	7.30	51.66	6.30	6.32	7.26	88

Treatments	Avg. no of sucker/ plant	Graft union height (cm)	Graft union diameter (mm)	Shoot length (cm)	Shoot diameter (mm)	Rootstock diameter (mm)	No. of leaves	Graft success (%)
tongue								
Bruno veneer	6.52	2.66	3.74	52.00	5.14	5.84	6.20	60
Bruno wedge	6.32	1.66	7.40	36.96	5.74	5.92	5.70	84
Hayward Oblong tongue	3.44	2.56	7.10	94.70	5.92	6.17	6.80	84
Hayward Oblong veneer	5.04	2.14	7.48	97.10	5.43	6.51	7.30	40
Hayward Oblong wedge	4.68	1.96	6.27	37.46	5.56	5.80	4.80	76
Hayward Oval tongue	5.04	2.38	6.46	57.90	5.34	5.93	6.56	92
Hayward Oval veneer	2.20	2.20	8.68	49.10	6.45	6.80	7.70	76
Hayward Oval wedge	3.56	1.68	6.75	69.40	5.88	6.16	7.73	84
Monty tongue	5.96	2.46	6.87	62.76	6.07	6.25	7.33	84
Monty veneer	6.24	2.40	8.45	40.10	5.43	6.39	6.40	72
Monty wedge	3.72	1.58	8.77	57.90	6.71	6.98	7.53	80
Mean	4.86	2.24	7.27	60.63	5.83	6.34	7.15	77.33
CV (%)	24.29	23.31	15.24	45.06	11.70	9.13	25.92	20.80
P value	0.00	0.03	0.00	0.00	0.01	0.04	0.02	0.051
LSD (0.05)	1.49	0.66	1.40	34.56	0.86	0.73	2.34	NS

In both years, the Allison variety of Kiwifruit grafted with wedge method gave maximum success rate. Taking average of both years, the Allison grafted with wedge method gave 100% final graft success followed by Allison with tongue method (92 %) and Hayward Oval with tongue (92%) (Figure 1).

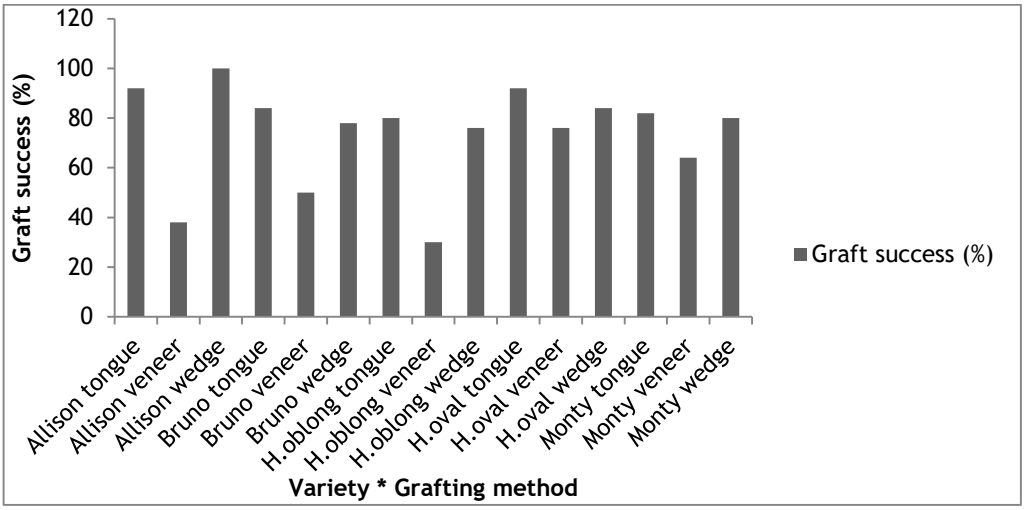

Figure1. Graft success (%) of different variety of Kiwifruit in different grafting method

Pandey et.al (2019) conducted an experiment at Bonch, Dolakha under callus house having restricted light and regulated temperature to enhance callus initiation for 2 months and transplanted in the main field. The effect of scion variety and wrapping materials on growth performance of kiwi seedling rootstock was studied and reported the maximum graft success (96.87%) and survival percentage of grafts (93.75%) in Allison variety which was statistically at par with Bruno and Hayward and the lowest graft success (73.44%) and survivability (64.21%) in Monty due to high mortality of the sprouted grafts. Sedaghathoor and Noie (2016) found that the highest graft union percentage (100%) was obtained under treatment cleft grafting × 'Bruno' rootstock and tongue grafting ×'Matua' rootstock at open field condition. The result of this study shows the higher graft success in tongue and wedge grafting. It might be due to the better attachment of cut surface of both rootstock and scion with formation of wound tissue for healing and cambial connectivity between stock and scion. Zenginbal (2007) in his study reported that among the grafting types, whip grafting was superior to chip budding and among varieties, Matua and Tomari were superior than others. Hartmann et.al (2007) reported that genetic factors had a significant effect on grafting success. So the varietal genetic composition may be crucial factor to graft success. To form a healthy graft union from two plants, it is dependent on their natural relationship (Sharma, 2002). The grafting success could be affected by several factors such as temperature, hygiene, pest and disease, humidity, developing capability of both scions (bud) and rootstock, grafting time and conservation of healing union against water loss and drying (Kaoka and Yılmaz, 1974; Tanimoto, 1994).

CONCLUSIONS

Graft success rate depends on scion variety and grafting method which influence various growth parameters and pomological traits of grafted plants such as plant height, leaves number, growth habit of the tree, time of fruit maturity and yield. From this study we can conclude that the different varieties of Kiwifruit prefer different grafting techniques. Only one method of grafting may not be suitable for all the varieties. All over, wedge grafting and tongue grafting gave better graft success rate in Kiwifruit than veneer grafting. In both years, graft success was better in Allison variety done with wedge grafting.

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IMPACT OF MICROFINANCE IN AGRICULTURE AND LIVESTOCK PRODUCTION; INSIGHTS FROM CENTRAL NEPAL

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ABSTRACT

This paper examines the impact of microfinance in agriculture and livestock in Dhading and Chitwan districts of Nepal. Municipalities within the districts were selected purposefully, and 60 respondents from each district were selected by simple random sampling method to comprise 120 respondents. The study showed significantly higher percentage of people participating in microfinance had self-sufficient food production. Probit regression analysis was done to estimate the impact of different predictor variables on farmer's participation in microfinance. Although the production, income and gross margin of rice and wheat and gross margin of livestock was found statistically higher among the farmers participating in microfinance, the expense for rice and wheat was also found significantly higher among the farmers participating in microfinance. The result of Probit regression analysis showed six variables namely age of household head, caste/ethnicity, education of household head, agricultural credit, livestock unit (LSU), and annual household income were statistically significant for farmer's participation in microfinance.

Keywords: Agriculture, livestock holding, microfinance, productivity, self-sufficiency

INTRODUCTION

The estimated population of Nepal is around 28.61 million and 17.4 percent of them are with the incidence of multidimensional poverty (NPC, 2019). Agriculture, including crop, livestock and fisheries, is a prime source of livelihood of Nepalese people and contributes 25.8 percent to national Gross Domestic Product (MOF, 2021). Agriculture in Nepal is characterized by large number of small and marginal farms with limited financial resources and hence they cannot apply optimal inputs and new production technologies for higher production. Many programs have been implemented for food security and improving crop production in Nepal. Among those microfinance programs are seen as poor targeted and rural based. Hence, various development strategies aimed at alleviating poverty are now invariably incorporating micro-finance as one of the key sectors in their programs.

Microfinance is defined as a sector of formal and non-formal financial institutions providing micro-savings, micro-credit, and micro-insurance services to the micro-

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economy thereby allocating scarce resources to the micro-investments (Seibel & K.C., 1998). Micro-credit normally means a credit of less than NRs. 30,000 and given without collateral and less paper-work (Paul, 2006). Microfinance is not simply banking for the poor; it is development approach with a social mission (Hansen & August, 2009) through catering the financial needs of economically active poor marginalized from the formal financial sector, be it for socio-cultural, systemic, geographic, or other reasons.

The introduction of Small Farmers Development Program (SFDP) by the government owned Agricultural Development Bank of Nepal (ADB/N) in 1975 marks the formal beginning of history of microfinance in Nepal. The program began after a multi-agency and multi-disciplinary field workshop of Food and Agriculture Organization/Asian survey on Agrarian and Rural Development (FAO/ASARD) in a number of countries including Nepal(Acharya S. , 2001). A pilot project in Sakhuwa Mahendranagar of Dhanusha district and Tupche of Nuwakot district was implemented with a broad humanistic goal of facilitating to achieve minimum desirable quality of life to the marginalized small farmers. It came into operation in the form of a pilot sub-project office (SPO) (Pyakuryal , 1997).

Micro-finance has been a particularly effective development intervention for the three basic reasons (Hansen & August, 2009); the service provided can be targeted specifically to the poor and the poorest of the poor; these services can make significant contribution to the socio-economic status of the targeted communities; and the institutions that can deliver these services can develop, within a few years, into sustainable organizations. It has, therefore, become necessary to study the impact of microfinance on efficiency performance of farms and agricultural production. The research is designed to conduct a thorough study to assess the impact of microfinance on farm performance, agricultural production and food security.

Nepal faces considerable development problems and challenges. Agricultural productivity is low and declining due to population pressure on marginal as well as agricultural lands. Nepal's limited resource, rapid population growth (1.35 percent per annum)(CBS, 2015), low land-man holding capacity (0.68 ha per capita), environmental degradation and widespread poverty are the challenges for the development. Around 85 percent people live in rural areas and have very limited opportunities to financial resources. The access to the financial services for the rural peoples is further hindered by the geographical limitations. It is estimated that 80 percent of total population in Nepal have no access to formal credit (Paul, 2006). As a result, informal financial institutions still dominate in most of rural areas. Even in places where facilities of credit exist, poorer households lacking collateral-suitable assets are considered risky borrowers (Sharma, 2004) and excluded because of the

strict collateral requirements and high transaction cost involved (Zeller & Sharma, 2000). Thus it is essential to make cheap credit available to the rural areas. The general objective of this study was to access the impact of microfinance on crop and livestock production.

METHODOLOGY

STUDY POPULATION, SAMPLE SIZE, SAMPLING TECHNIQUE AND METHOD OF DATA COLLECTION

The study was carried out in Dhading and Chitwan districts. The research sites, Nilakantha Municipality and Bharatpur metropolitan city were selected purposefully to include peoples from different geographical locations. A total of 120 farming households,60 from each municipality, were selected as study sample. Simple random sampling method was adopted to select the sample from the population. To make a comparative study, with and without approach for microfinance was adopted. Interview schedule was prepared to collect primary information from the selected farmers.

METHODS AND TECHNIQUES OF DATA ANALYSIS

The collected information was coded, entered and edited with the help of Microsoft excel and analysis was done with the help of STATA (Version 14.2).Both primary and secondary data was analyzed using mean difference test, independent t-test and probit test.

With and without approach

This approach compares the conditions of households who have participated in the microfinance programs and those who haven't. The crop and livestock production and productivity of the household participated in microfinance program is compared to that of the households which haven't participated in the microfinance.

Probit regression model

Probit regression model is a statistical model which aims to establish a relation between probability values and explanatory variables and to ensure that the probability value remains between 0 and 1(Gujrati, Econometrics by example, 2015).In the Probit model, suppose Y_i be the binary response of the farmers and take only two possible values; Y = 1, farmer with microfinance and Y = 0, farmer without microfinance. Suppose X be the vector of several explanatory variables affecting to the farmers participating in microfinance andβ, a vector of slope parameters, which measures the changes in X on the probability of the farmers with and without

participation in microfinance programs. The probability of binary response was defined as follows:

If Yi = 1; Pr ($Y_i = 1$) = P_i
$Y_i = 0$; Pr ($Y_i = 0$) = 1-P_i

Where,
P_i = E (Y = 1/x) represents the conditional mean of *Y* given certain values of *X*.
There were several factors that affect the farmer's participation in microfinance. Decision to adopt at higher level might be influenced by several socioeconomic, institutional and financial conditions of the responding farmer. The aim of the model is to predict the influence of variables (*X*) on the probability of participating in microfinance (*Y*, dependent variables). According to this, in the probit model the likelihood of farmers to participate in microfinance is a non-linear function of variables.

Pr(Y=1) = (*X* beta)
Probit model was used to quantify the probability of different factors to participate in microfinance programs.

MODEL SPECIFICATION

The probit model specified in this study to analyze farmer's participation in microfinance was expressed as follows:

$$Pr(Y=1) = f(b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10} + b_{11}X_{11} + b_{12}X_{12})$$

Where,
Pr (Y=1) = Probability score of participating in microfinance
X_1= Districts
X_2= Age of household head (years)
X_3= Gender of household head
X_4= Ethnicity of household head
X_5= Education of household head
X_6= Occupation of household head
X_7= House type
X_8= Land holding
X_9= Credit
X_{10}= LSU
X_{11}= Annual income of household
$b_1, b_2 \ldots b_{11}$= Probit coefficient

RESULTS AND DISCUSSIONS

DISTRIBUTION AND SIZE OF LAND HOLDING

The average land holding was found similar in Dhading and Chitwan district (0.36 ha in an average) (Table 1). The average lowland holding of both study area (0.30 ha on average) was significantly higher than upland holding (0.06 ha on an average).

Table 1. Land holding pattern of the sample households by respondent category

	Average land holding (ha) per household		
Districts	Lowland	Upland	Total land
Dhading	0.26	0.10	0.36
Chitwan	0.34	0.02	0.36
Average	0.30	0.06	0.36

LIVESTOCK HOLDING

The average of livestock ownership was calculated in Livestock Standard Unit (LSU) to aggregate different types of livestock owned by respondent per household (Table 2). Aggregate LSU is calculated as(Adhikari J. , 2000):LSU= 1 (cow/bull) + 1.5 (buffalo) + 0.4 (goat/sheep) + 0.6 (swine/Pig) + 0.02 (poultry). As indicated in Table 2 average LSU for sample area in Dhading district was significantly higher (11.40) then that for Chitwan district (3.33).

Table 2. Livestock unit (LSU) in study area

Districts	Average LSU
Dhading	11.4058
Chitwan	3.3325
Total average	7.3692

FARMERS PARTICIPATION IN MICROFINANCE

Out of 120 households surveyed 78 households have participated in microfinance and 42 households have not participated in microfinance. The further details of farmer's participation in microfinance in both districts is given in the figure 1.

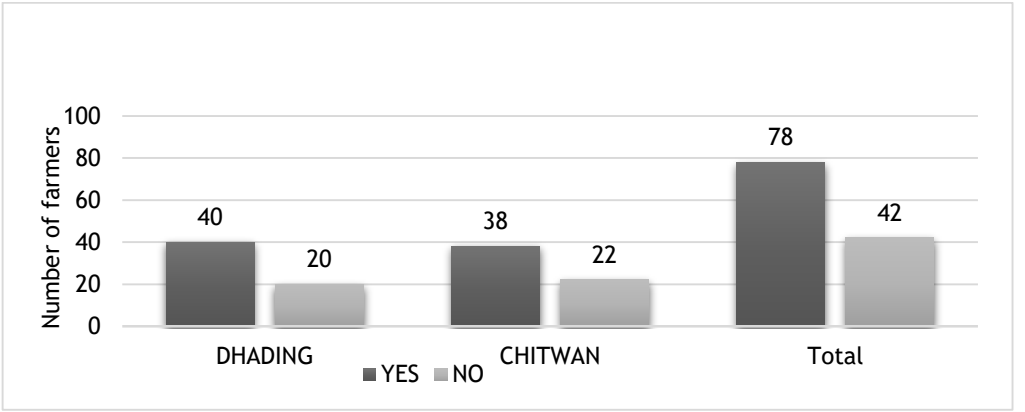

Figure 1. Farmers' participation in microfinance

FOOD SELF-SUFFICIENCY AND MICROFINANCE

A comparison was made between people's involvement in microfinance and food self-sufficiency as shown in Fig. 2 and Fig. 3. It showed that people who are involved in microfinance have higher food self-sufficiency (65 percent) than the people who are not involved in microfinance (62 percent). Also it was seen that 5 percent farmers without microfinance have food sufficient for less than 3 months.

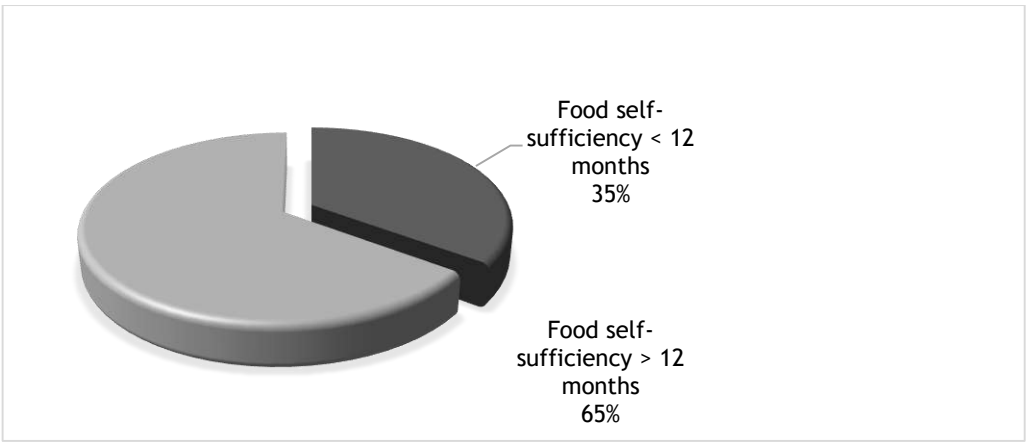

Figure 2. Food self-sufficiency with microfinance

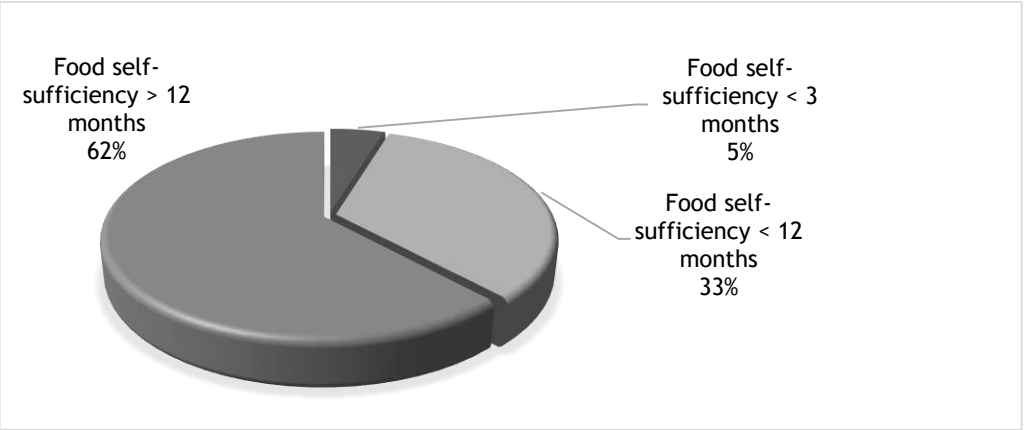

Figure 3. Food self-sufficiency without microfinance

IMPACT OF MICROFINANCE ON CROP AND LIVESTOCK PRODUCTION

Among the crops, rice and wheat production were significantly different with microfinance and without microfinance (Table 3). The overall average rice production in the study area was2.20 Mt. 22.07 with 2.71 Mt. produced by farmers participating in microfinance and 1.55 Mt. produced by farmers not participating in microfinance which is statistically significant difference (P value =0.000). Similarly, average wheat production of the study area was 0.31Mt.with 0.40 Mt. produced by farmers participating in microfinance and 0.26 Mt. produced by farmers not participating in microfinance which was also significant at 1 percent level. (Sulemann & Adjei, 2015), also found that microfinance was positively correlated with production of rice with correlation coefficient 0.798 which is considered high. The average milk production per household per year was found to be around 6122 liters, which was statistically similar among microfinance participants and non-participants.

Table 3. Production from crops and livestock with farmer's participation in microfinance

Variables	Overall (N=120)	With Microfinance (n=78)	Without Microfinance (n=42)	Mean difference	T-Value	P-Value
Rice Production (Mt.)	-2.20	2.71	1.55	1.15***	5.319	0.000
Maize Production (Mt.)	0.03	0.03	0.03	0.00	0.543	0.588
Wheat Production (Mt.)	0.31	0.40	0.26	0.13***	2.602	0.010
Milk Production (Mt.)	6121.78	934.76	9150.25	-8215.48	-1.117	0.266

Note: *** indicates significance at 1 percent level.

IMPACT OF MICROFINANCE ON CROP AND LIVESTOCK INCOME

There was significant difference in the income from rice and wheat at 1 percent level among the farmers with microfinance and without microfinance (Table 4). Similar difference in income from agricultural crops was also found by(Girabi & Mwkaje, 2013) between peoples participating in microfinance and not participating in microfinance. The income form the maize and livestock was statistically similar.

Table 4. Income (in NRs) from crops and livestock with farmer's participation in microfinance

Variables	Overall (N=120)	With Microfinance (n=78)	Without Microfinance (n=42)	Mean difference	T-Value	P-Value
Income from Rice	84817	139722	55252	84470***	4.133	0.000
Income from Maize	22324	24407	21202	3204	0.710	0.479
Income from Wheat	9069	11621	7694	3926***	2.649	0.009
Income from Milk Production	113606	128482	105596	22885	0.591	0.556

Note: *** indicates significant at 1 percent level.

IMPACT OF MICROFINANCE ON CROP AND LIVESTOCK EXPENSE

The independent t-test showed that there was significant difference among the people with microfinance and without microfinance with respect to expense for rice at 1 percent level and wheat at 5 percent level respectively (Table 5), whereas the expense for maize and livestock was not statistically significant.

Table 5. Expense (in NRs.) for crops and livestock with farmer's participation in microfinance

Variables	Overall (N=120)	With Microfinance (n=78)	Without Microfinance (n=42)	Mean difference	T-Value	P-Value
Expense for Rice	24435	39976	16065	23911***	4.961	0.001
Expense for Maize	10501	8769	11433	-2664	-1.121	0.264
Expense for Wheat	4573	5906	3854	2052**	2.352	0.042
Expense for Livestock	19149	18653	19416	-762	-0.099	0.921

Note: ** and *** indicates significant at 5 percent and 1 percent level respectively.

IMPACT OF MICROFINANCE ON CROP AND LIVESTOCK GROSS MARGIN

The gross margin analysis of selected crops and livestock enterprises among the farmers with and without microfinance participation revealed significantly higher

gross margin of rice, wheat and livestock among the microfinance participating farmers while the gross margin of maize was insignificantly higher among the microfinance participants (Table 6). Significant relationship between microfinance and crop production was also found by (Eliasu, Al-Hassan, Rose, & Mohammed, 2014), where farmers in microfinance increased crop production by one third. An 39.13 percent increase in adult buffalo population due to credit form microfinance was found by (Taj, Bashir, Shahid, & Shah, 2012), the same research showed more than 81 percent increase in buffalo young stock and 100 percent in goat population after micro-credit utilization, which could lead to higher gross margin from livestock.

Table 6. Gross Margin (in NRs.) from crops and livestock with farmer's participation in microfinance

Variables	Overall (N=120)	With Microfinance (n=78)	Without Microfinance (n=42)	Mean difference	T-Value	P-Value
Gross Margin of Rice	69326	133161	34953	98208***	3.875	.000
Gross Margin of Maize	13197	14360	12571	1789	0.284	.777
Gross Margin of Wheat	4503	7597	2837	4760***	3.054	.003
Gross Margin of Livestock	95136	194222	41782	152440***	3.883	.000

Note: *** indicates significant at 1 percent level.

FACTORS AFFECTING FARMER'S PARTICIPATION ON MICROFINANCE IN STUDY AREA

To identify the factor influencing the participation of microfinance, probit model of regression was used. Farmers in the study area were found engaged in microfinance based on various factors. The farmer's participation in microfinance in the study area was categorized into binary response of their engagement =1 and 0 otherwise.

Table 7. Summary of the variables used in probit regression

Variables	Description	Obs	Mean	Standard deviation	Min.	Max.
Dependent variable MICROFINANCE	Participating in microfinance programs. (1= with microfinance, 0= without microfinance)	120	0.65	0.47	0	1
Independent variables						
DISTRICT#	District of the respondent (1=Dhading, 0= Chitwan)	120	0.5	0.50	0	1
AGE_HH	Age of the household head	120	51.75	12.37	27	85

	(in years)					
GENDER_HH#	Gender of the HH (1= Male, 0= female)	120	0.92	0.26	0	1
ETHNICITY#	Caste of HH (1= Brahmin/Chhetri, 0= otherwise)	120	0.62	0.48	0	1
EDUCATION_HH#	Education of the HH (1= literate, 0= illiterate)	120	0.75	0.43	0	1
OCCUPATION_HH	Occupation of HH (1= Agriculture, 0= otherwise)	120	0.78	0.41	0	1
HOUSE_TYPE#	Type of house (1=Pakki, 0=Kachhi)	120	0.20	0.40	0	1
LAND_HOLDING	Total size of cultivated land (in hectares)	120	0.37	0.32	0	2.1
CREDIT#	Credit from microfinance for agriculture/livestock	120	0.46	0.50	0	1
LSU	Livestock standard unit	120	54.13	386.06	0	3006
LOG_INCOME	Total Farm income (Rupees/ha)	120	12.02	0.75	10	14.3

Marginal change in probability (marginal effects after Probit) was evaluated at the sample means. Probit regression analysis was focused on the 120 respondents of the study area with or without participating on the microfinance. The wald test (LR chi^2) for the model indicated that, the model had good explanatory power at the 1% level. The Pseudo R^2 was 0.634. For the interpretation of the model, marginal effects were driven from the regression coefficients, calculated from partial derivatives as a marginal probability as shown in Table 8.

Probit regression analysis showed that, six out of eleven variables were statistically significant for farmer's participation in microfinance, they were age of household, caste, education of household, credit, livestock standard unit and income of the household. Five other variables namely district, gender of household head, occupation of the household head, house type and land holding were statistically non-significant.

Higher the age of the household head, lower will be the participation in microfinance. The study revealed that, the age of the household head was negatively significant at 1 percent level and keeping other variables constant, a unit increase in age of household head would reduce the probability of participating in microfinance by 1.5%. This might be due to the increased dependency on higher age of household heads (Ayamga, Sarpong, & Brempong, 2006) also found the similar findings.

Similarly, farmer's participation in microfinance was negatively significant with ethnicity at 10 percent level. On moving from Brahmin/Chhetri to Janajati and Dalits,

the farmer's participation on microfinance would be decreased by 3.5% keeping other variables constant. Farmer's participation on microfinance was also negatively significant with education of household head at 10 percent level. When the household head becomes literate the probability of participating in microfinance would reduce by 6.3%. The results are consistent with (Karanja & Mwaura, 2016) who found that when women's level of education is lower the probability of joining microfinance was higher. Farmer's participation on microfinance was positively significant with credit taking for agriculture at 1 percent level. When a household takes credit the probability of participation in microfinance would increase by 47%.

Farmers participation in microfinance was also negatively significant with livestock unit at 5 percent level. It means a unit increase in livestock unit will decrease the farmer's participation in microfinance by 0.02%. The reason for this may be that the people with higher livestock unit will have income round the year and they need microfinance organizations less than others. Farmers participation in microfinance was positively significant with household income at 5 percent level. With an increase in household income, the probability of participating in microfinance would increase by 2%. This can be related that farmers with higher income participate microfinance for saving purposes. However, this contradicts the findings from (Nxumalo & Olaele, 2013).

Table 8. Factors affecting people's participation on microfinance in the study area

Variables	Coefficient	Standard error	Z	P>|Z|	dy/dx
District	-0.541	0.472	-0.96	0.339	-0.015
Age hh	-0.059***	0.018	-3.12	0.002	-0.001
Gender hh	0.694	0.773	0.90	0.369	0.012
Caste	-0.800*	0.428	-1.87	0.062	-0.035
Education hh	-1.020*	0.532	-1.92	0.055	-0.063
Occupation hh	-0.308	0.570	-0.54	0.589	-0.012
House type	-0.781	0.512	-1.53	0.127	-0.165
Land holding	-0.467	0.576	-0.81	0.417	-0.150
Credit	4.068***	1.204	3.38	0.001	0.470
Lsu	-0.752**	0.031	-2.41	0.016	-0.002
Log income	0.632**	0.265	2.38	0.017	0.020
# dy/dx is for discrete change of dummy variable from 0 to 1.					
Summary statistics					
Number of Obs.	120				
LR $chi^2(11)$	98.26				
Prob> chi^2	0.000				
Pseudo R^2	0.6324				

CONCLUSIONS

Microfinance can potentially reduce vulnerability by helping rural people by diversifying their source of household income, increase their savings, expand their options for credit, improve household money arrangement and thus increase the farm productivity by increasing the access to agricultural inputs. In the study, higher percentage of people participating in microfinance was found to have self-sufficient food production. The participation in microfinance was found to have improved the production and gross margin of rice and wheat. Similarly, it has improved the gross margin from livestock too. Probit regression analysis showed that, six variables were statistically significant for farmer's participation in microfinance, they were; age of household head, ethnicity, education of household head, agricultural credit, LSU and annual household income. Among them age of household head, caste, education of household head, and LSU had significant negative impact and agricultural credit and annual household income had significant positive impact on farmer's participation in microfinance. Thus, effective monitoring and evaluation of the microfinance programs along with frequent follow ups would be recommended to ensure appropriate utilization of microfinance credits.

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INDIAN MUSTARD AND BUCKWHEAT AS TRAP PLANTS OF DIAMONDBACK MOTH (*Plutella xylostella* L.) IN CABBAGE CULTIVATION

B. Sapkota[1*], R. Regmi[1], R. B. Thapa[1] and S. Tiwari[1]

ABSTRACT

Diamondback moth (Plutella xylostella) is an important pest of crucifer crops. It greatly reduced both yield and crop quality on cabbage (Brassica oleracea var. capitata). The field study was conducted to evaluate the efficacy of two trap plants: Indian mustard (Brassica juncea), and Buckwheat (Fagopyrum esculentum) from November 2018 to March 2019 in Chitwan, Nepal. Diamondback moths' population were similar in trap plants but was significantly lower as compared to the control plot. Diamondback moth larvae population was lower during early vegetative growth stages whereas trapping efficacy of trap crops were gradually reduced with the development of maturity in trap plants. The lowest damage of wrapper leaves were obtained in Indian mustard deployed trap plant followed by buckwheat trap plant and control respectively; however, the yield was similar in all treatments. In addition, natural enemies were observed higher in traps crops deployed plots compared to the control plots. Therefore, trap plants can be used as an alternative sustainable pest management tool to manage diamondback moth as well as increase the abundance of natural enemies.

Keywords: Buckwheat, cabbage, diamondback moth, indian mustard, trap plant

INTRODUCTION

Cabbage (*Brassica oleracea* var *capitata* L.) is the most popular vegetable crop in Nepal. The edible portion of cabbage is "vegetative bud". It is eaten as a vegetable in curries, soups, pickles, and salads. In Nepal, the total area under cabbage cultivation was 30311 ha with a yield of 17.11 mt/ha in the fiscal year 2018/19, whereas, in Chitwan district, the area under cabbage production is 340 ha with the productivity of 15.53 mt/ha in the fiscal year 2018/19 (MoALD, 2019).

Several factors are responsible for the decreased productivity of cabbage in Nepal including inadequate supply of quality inputs (Sharma, 2019) and insect pest damage (Kafle *et al.*, 2012). Insect pests namely diamondback moth (*Plutella xylostella* Linn.), cabbage butterfly (*Pieris brassicae* Linn.), cabbage aphid (*Brevicoryne brassicae* Linn.) and mustard aphid (*Lipaphis erysimae* Kalt.), cabbage borer (*Hellula undalis* Fab.), cabbage looper (*Trichopulsia ni* Hub.) are major pests on cabbage and cauliflower (Yadav and Malik, 2014). Diamondback moth is one of the well-known and

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destructive insect pests of crucifers around the world. About 80-90% loss is caused by this pest in cabbage crop (Robert and Wright, 1996). Recent studies have shown that the trend of pesticide use is increasing in Nepal (Sharma *et al.*, 2013), and 90% of total pesticides are used in vegetable farming (Atreya and Sitaula, 2010). So far diamondback moth has been reported to develop resistance against 877 different insecticides of more than ten modes of action classes (Mota-Sanchez and Wise, 2020).

In Nepal, integrated pest management (IPM) is being used as an alternative method to replace the intensive use of insecticide against this pest (Upadhaya, 2003). This has improvised the concept of growers to minimize the use of harmful chemical pesticides to control diamondback moths and reduced their intensity in the field crops. Eventually, the use of botanical products, bio-pesticides, habitat manipulation techniques, etc. has been developed. The use of trap plants is the alternative pest management strategy for the various categories of insect pests that are farmers friendly and cheap (Tiwari *et al.*, 2019). Trap plants either trap the pest in the border by restricting the movement of pests from the perimeter of the field or attract the pest into a more preferred plant (Hokkanen, 1991). The various implementation types of trap crops based on temporal or spatial deployment are perimeter, sequential, push-pull, etc. (Hokkanen, 1991; Shelton & Badenes-Perez, 2006). Conventional trap cropping for lepidopteran pests relies on the capacity of trap crops to attract for oviposition and keep the pest away from the cash crop (Badenes-Perez *et al.*, 2005). Hence, this study was undertaken to develop alternative pest management for *P. xylostella* in cabbage fields and reduce pesticide amount in vegetable farms.

MATERIALS AND METHODS

EXPERIMENTAL SITE

The research was conducted at Bharatpur Metropolitan City- 18, Chitwan from November 2018 to March 2019. The site is located at the latitude of 27^0 63'North; longitude 84^0 28' and altitude of 168 meters above sea level. The experiment was designed by laying three main plots with long side running East-West. The plot was further divided into six small cabbage plots and trap plants were sown in the perimeter of each main plot. Indian mustard, *Brassica juncea* (L.) (Czern.) (var. Pusa Bold) and Buckwheat, *Fagopyrum esculentum* Moench (var. Mithe Fapar-1) were used as trap plants in the experiment. Trap plants deployed field was 8 m distance from control plots (Fig 1). The area of each cabbage plot was 6.75 m^2 with 4 rows and 5 cabbage plants in each row. Row to row and plant to plant spacing was maintained at 60 cm and 45 cm, respectively.

Both trap plants were sown in the perimeter of the cabbage field just before 15 days of cabbage transplanting. Two rows of trap plants were sown in a continuous line or row with 15 cm intra-spacing and 10 cm outside of the cabbage plot. The net area

occupied by each trap plant was 6.66 m^2 outside of cabbage plots (Fig 1). They were sown 15 days before to synchronize the plant vegetative period with cabbage growth and pest incidence.

Table 1. Treatments in the experimental field

Treatments	Treatment details
Treatment 1	Trap plant: Indian mustard (*Brassica juncea*) in the perimeter of the cabbage plot
Treatment 2	Trap crop: Buckwheat (*Fagopyrum esculentum)* in the perimeter of the cabbage plot
Treatment 3	Control (cabbage only)

AGRONOMIC PRACTICES AND PLANTING MATERIALS

Cabbage cv "Green Coronet" was used for this study. The experimental field was plowed thoroughly as required by disc harrow. FYM was used @ 20 t/ha in the field. Thirty-five days old seedlings of 2- 4 true leaf stages were transplanted in the field on 28th December 2018. Basal dose of fertilizer was applied @ 120:80:60 kg NPK/ha in which half dose of N and a full dose of P and K were applied and the remaining dose (i.e., 50kg/ha) N was applied after 45 days of transplanting (DAT) as a side dressing in the field. Different intercultural practices such as weeding, earthing-up, and irrigation were done from time to time on a need basis.

LAYOUT OF THE EXPERIMENT

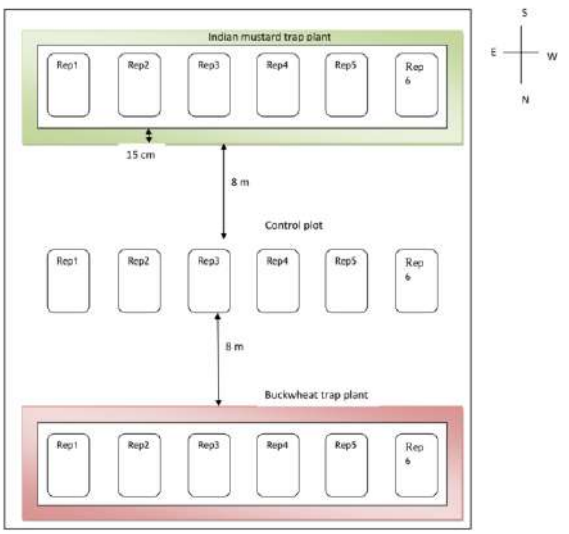

Figure 1. Layout of the experimental field

DATA COLLECTION AND ANALYSIS

Six cabbage plants from each treatment plot were randomly selected for data collection. The diamondback moth larvae populations were directly counted by observing the whole outer leaves of cabbage. Data were recorded starting from 50 DAT after the adult moth begin to appear in Wotta-T trap placed for monitoring in nearby cabbage field. It was then recorded evenly after 4 days of the first count up to ten times. Field collected insect counting data were square root transformed before ANOVA (Gomez & Gomez, 1984). The data was statistically analyzed by using analysis of variance using the R-Studio (Version 3.6.1) software package.

RESULTS

EFFICACY OF TRAP PLANTS

In most of the recordings, the numbers of diamondback moths was significantly lower in trap deployed cabbage plots as compared to control plots but were not significantly different between trap plants. However, the non-significant population of diamondback moth was similar among the trap plants, and control at 66 DAT, 74 DAT, 78 DAT, and 82 DAT (Table 2).

Table 2. Mean number of diamondback moth recorded on cabbage plants adjacent to each trap plant in different time interval

Observation / Treatment	50 DAT	54 DAT	58 DAT	62 DAT	66 DAT	70 DAT	74 DAT	78 DAT	82 DAT	86 DAT
Indian mustard	1.38^{b}	1.70^{b}	1.17^{b}	1.86^{b}	3.09	2.21^{b}	3.66	3.10	3.91	4.16^{b}
Buckwheat	1.64^{b}	1.54^{b}	1.58^{b}	2.40^{b}	2.82	2.33^{b}	3.17	3.84	4.14	4.52^{b}
Control	2.39^{a}	2.68^{a}	3.06^{a}	3.34^{a}	3.23	3.34^{a}	3.75	3.72	4.48	5.02^{a}
Means	1.808	1.977	1.939	2.539	3.049	2.633	3.531	3.658	4.182	4.569
Sem(±)	0.052	0.022	0.029	0.051	-	0.017	-	-	-	-
CV (%)	31.16	18.64	21.54	21.82	-	12.45	-	-	-	-
p-value	0.028	<0.001	<0.001	0.002	0.547	<0.001	0.297	0.089	0.073	0.007

DAT: Days after transplanting; CV: coefficient of variation; Values with the same letters in a column are not significantly different at 5% by DMRT (Duncan's multiple range test)

CABBAGE DAMAGE AND YIELD PATTERN IN TRAP PLANTS

The biological yield and net yield of cabbage were non-significant both in trap plants used field and control. However, the number of damaged wrapper leaves per plant was observed highly significant. The highest number of damaged wrapper leaves in cabbage plants was observed with control (6.37) followed by buckwheat (5.16) and Indian mustard (3.73) (Table 3).

Table 3. Cabbage yield (biological and net) and mean number of damaged wrapper leaves in cabbage field adjacent to each trap plant and control plots

Treatments	Biological yield (mt/ha)	Net yield (mt/ha)	Number of damaged wrapper leaves/plant
Indian mustard	78.44	54.94	3.73^{c}
Buckwheat	74.53	52.28	5.16^{b}
Control	69.58	44.17	6.37^{a}
Means	74.19	50.46	5.09
Sem(±)	-	-	0.06
CV (%)	-	-	11.96
p-value	0.555	0.314	<0.001

CV: coefficient of variation; Values with the same letters in a column are not significantly different at 5% by DMRT (Duncan's multiple range test)

POTENTIAL NATURAL ENEMIES

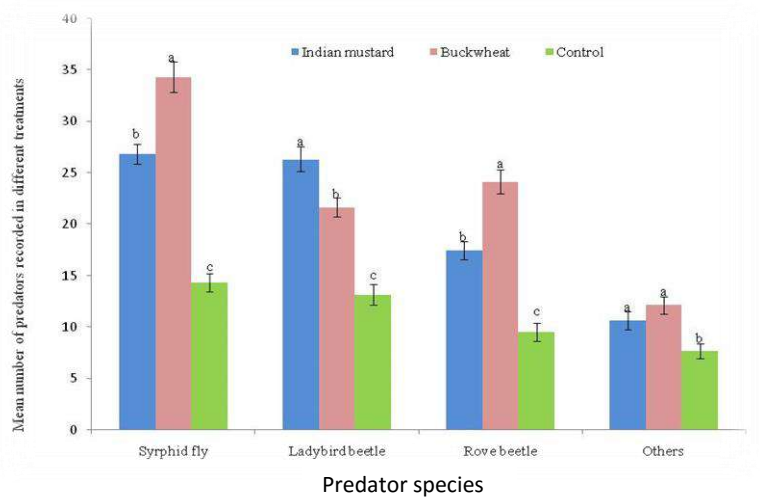

Figure 2. Mean number of predators; syrphid fly (adult and larvae), ladybird beetle (adult and larvae), rove beetle and other observed in trap deployed cabbage plot and control plot. Letters are used to denote the significant different treatments from each other; error bars are standard error of the mean LSD (5%), (df=10).

Number of beneficial predators such as syrphid flies (*Syrphus spp.*) (Syrphidae: Diptera), ladybird beetle (*Coccinella septempunctata* L.) and rove beetle were significantly higher in trap plants deployed cabbage plot compared to control plot (Fig 2). Significantly higher *Syrphus spp.* and rove beetle populations were observed in buckwheat deployed cabbage plots followed by Indian mustard deployed trap and the lowest in control cabbage plots (Fig 2). But, the ladybird beetle (*C. septempunctata)* population was significantly higher in the Indian mustard trap followed by buckwheat deployed and control cabbage plots. Other potential beneficial predators such as ants (Formicidae: Hymenoptera), braconid wasps (Braconidae: Hymenoptera), spiders (Arachnids), carabids (Carabidae: Coleoptera), wasps (Ichneumonidae: Hymenoptera), etc. were significant in trap and control cabbage plots but statistically at par between two trap deployed cabbage plots.

DISCUSSIONS

For reducing pesticide pressure in conventional pest management strategies, trap plants are an appealing option. When trap plants maintain harmful pest populations below the damage threshold level, they become an efficient way to minimize insecticide application (George *et al.*, 2019). Habitat manipulation by planting different border trap plants and non-crop origin can also conserve natural enemies and becomes a more efficient biological pest control strategy. Habitat manipulation can also result in a more effective biological pest control strategy by conserving natural enemies (Landis *et al.*, 2000). In this study, Indian mustard treatment helped reduce the incidence of *P. xylostella* during the initial growth phase. Then, the efficacy of traps remained in decreasing order. Inconsistency result of Indian mustard was observed for trapping diamondback moth. A similar result was stated by Smyth *et al.* (2003), who concluded that oviposition preference differed significantly among pre-flowering Indian mustard as a trap plant with growth stages of cabbage. In other observations, Srinivasan and Moorthy (1992) also performed sowing Indian mustard 15 days before and a second time 25 days after planting the main crop (cabbage) to maintain the plant population and floral density long-lasting to observe the effect of the trap. Badenes-Perez *et al.* (2005) evaluated that Indian mustard was highly attractive for diamondback moth Karimzadeh and Besharatnejad (2019) suggested that Indian mustard using trap plant could be recommended for the diamondback moth control, including the highest attraction of diamondback moth adults towards Indian mustard trap plant.

As a trap for diamondback moth, buckwheat was more effective during the early vegetative growth period i.e. up to 65 days of transplanting of cabbage. In a similar study, early floral densities of buckwheat in border effectively check egg, larval or pupal densities of diamondback moth in cabbage fields (Lee & Heimpel, 2005). The sudden rise of infestation of diamondback moth was observed in those plots where trapping boundary with buckwheat was applied. This sudden rise in infestation may

be due to a decrease in floral density of buckwheat trap while flowers start to convert into a fruit-setting phase which leads to a decrease in the nectar of flowering buckwheat. Bohinc and Trdan (2013) also mentioned that the developmental stage of the trap determined the intensity of feeding by pests and other predators. Trap plants could be maintained with flowering or non-flowering plants that provide any form of ecosystem services such as shelter, nectar, alternative host, and pollen (Tiwari *et al*., 2018). For the better growth and development of insect predators and parasitoids, floral nectar that is rich in source of sugar, protein, lipids and other compounds are vital to them (Nicolson and Thornburg, 2007). Similar findings were demonstrated when *Diadegma semiclausum* (Nilsson *et al*., 2016), and *D. insulare* (Lee & Heimpel, 2005) had access to the nectar of flowering buckwheat plants, larval parasitism of diamondback moth was increased. Biological control of insect pests could be improved by providing habitat diversification (Landis *et al*., 2000) and natural enemies with food resources such as floral nectar within the production field. Joshi *et al*. (2000) reported that cabbage with buckwheat or potato-buckwheat-mustard is one famous crop combination to achieve the various noxious pest controls within the agro-ecosystem.

CONCLUSIONS

The study demonstrates that *B. juncea* and *F. esculentum* are the potential trap plants for the diamondback moth. The higher efficacy of both trap crops was observed during the early growth stage when maximum foliage and flowering period occurred. Meanwhile, a higher population of beneficial predators such as syrphid fly, ladybird beetles, rove beetle was observed in trap crops deployed cabbage fields. This finding works as an alternative pest management option for farmers in developing countries.

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EFFECT OF GIBBERELLIC ACID (GA_3) ON YIELD AND FRUIT QUALITY OF TABLE GRAPE VAR. HIMROD IN KATHMANDU VALLEY, NEPAL

P. Poudel[1]*, P.N. Atreya[2] and K.C. Dahal[1]

ABSTRACT

The experiment was conducted at Warm Temperate Horticulture Center, Kirtipur, Kathmandu, Nepal with an aim to improve the yield and fruit quality of seedless table grape var. Himrod. Different treatments of GA_3 (0 ppm,10 ppm, 20 ppm, 30 ppm, 40 ppm) were applied for two times on grape bunches after berry set. The quantitative and qualitative attributes of bunch and berry were recorded. Berry size, berry weight, berry volume, bunch weight and berry color were improved significantly in GA_3 treated grape bunches whereas TA was significantly decreased. The effect of GA_3 on berry diameter had significant impact on berry weight and berry volume, and thus in yield. As the yield of a vine is the product of bunch number and bunch weight, GA_3 influenced the current season bunch weight by improving the berry attributes, and also affected quality attributes of grape berries in var. Himrod.

Keywords: Berry, bunches, GA_3, PGR, quality

INTRODUCTION

Grape (*Vitis vinifera* L.) belonging to the family vitaceae, is one of the earliest fruit known since civilization, popular for its nourishing, delicious and refreshing fruits (Jegadeeswari *et al.*, 2010). Dahal *et al.* (2017) has stated that grape can be consumed in diversified forms viz. fresh fruit, drinks as juices, wines, beverages and medicines, and stored as raisin thus, grape has its identity as worldly fruit. It is one of the most precious fruit of the temperate regions, but successfully grown in the tropical and sub-tropical agro-climatic regions too. In Europe, grape is the major ingredient for preparation of wines of various brands from the medieval period but in African and Asian countries, grape is more preferred and consumed as fresh fruit or raisin (Chattopadhyay, 2012). In Nepal, grape cultivation was supposed to be started more than 70 years ago at the time of Rana regime (Dahal *et al.*, 2017). Atreya *et al.* (2015) mentioned the grape cultivation covered an area of about 20 ha with total fresh grapes production of around 76 tonnes annually in Nepal. In recent years, commercial vineyards are establishing which will certainly increase area and productivity of grapevine in Nepal. In Nepal, various table grape cultivars such as, 'Thompson seedless', 'Perlette', 'Himrod', 'Beauty Seedless', 'Steuben', 'Kyoho', 'Black Olympia' etc were subsequently introduced from Japan and India (Joshi, 1986).

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Among several imported varieties, 'Himrod' is considered one of the promising seedless variety, developed by crossing 'Thompson seedless' and 'Ontario' in State Agricultural Experiment Station, New York Botanical Garden (Maul *et al.*, 2020). 'Himrod' variety is one of the popular early ripening table grapes, grown in warm climate (Dahal *et al.,* 2017), which has attractive bunch color, excellent taste, firmness and of parthenocarpic nature (Maul *et al.*, 2020) but the small berry size is a distractive feature (Miyoshi *et al.,* 1997). For table grapes, berry size is one of the important criteria, influencing consumer's preference in the global market (Zoffoli *et al.*, 2009). Attractive visual features like bigger berry size, weight, proper shape, appropriate color development etc are vital for proper marketable quality and to fence higher price (Marzouk and Kassem, 2011).

Since 19th century, several cultural methods like girdling, pruning, berry thinning and spraying plant growth regulators (PGRs) have been used to improve quantitative and qualitative characteristics of grapes (May, 2004). Among these practices, PGRs application was considered effective in improving yield and quality of grape berries (Dokoozlian, 1998; Loubser and Wolf, 1994; Srivastava and Handa, 2005). In commercial grape cultivation, application of PGRs especially Gibberellic acid (GA_3) is popular for enhancement of vegetative growth parameters like bunch weight, berry length, berry diameter, berry weight and size etc. and qualitative characteristics like Total Soluble Solid (TSS) and Titratable Acidity (TA) in several table grape varieties including 'Thompson Seedless', 'Flame Seedless', 'Ruby Seedless', 'Sovereign Coronation', 'Italia' and so on (Dokoozlian, 1998; Ezzahouani *et al.*, 1985; Miele *et al.*, 2000; Reynolds and Savigny, 2004; Shaaban *et al.*, 1989). GA_3 is used widely for improving yield and fruit quality of grape when the inflorescence is about 8 cm length for bunch elongation, at full bloom stage for berry thinning, and at 4-10 mm berry size for berry enlargement; however, the specific stage of GA_3 treatment varies among cultivar, environment and the purpose of the treatment (Christensen, 2000; Dokoozlian, 1998; Hed *et al.*, 2011; Molitor *et al.*, 2012; Van Der Merwe, 2014). GA_3 can be applied either by spraying the entire vine or by localized spraying/dipping of the individual bunch at recommended phenological stage, definite dose, and specific environmental condition; as these criteria are sensitive to desired outcomes (Molitor *et al.*, 2012; Mullins *et al.,* 1992; Orth, 1990; Weaver and Pool, 1971).

With existing climatic suitability and assuring market, viticulture has tremendous possibilities in Nepal as the demand for fresh grapes is increased day by day due to increment in population, increased awareness and purchasing power of the individuals Thus, the major objective of this investigation was to identify appropriate dose of GA_3 for improving the yield and quality of seedless table grapes.

MATERIALS AND METHODS

The experiment was conducted in an established vineyard (>30 years old vines) of Warm Temperate Horticulture Centre (WTHC), Kirtipur, Kathmandu, Nepal from May, 2020 (Baisakh, 2077) to July, 2020 (Ashad, 2077). For experimental set up, the vines were arranged in a Randomized Complete Block Design (RCBD) having 5 treatments with 4 replications. Ten bunches of similar growth stage were tagged from a vine for treatment application, while other bunches of a vine were remained untouched. A vine was considered as a replicate. So, there were total 20 experimental vines of var. Himrod. Different concentrations of GA_3 (10 ppm, 20 ppm, 30 ppm, 40 ppm and control) were allocated as treatments. Two applications of GA_3 were carried out after berry set. The first application of GA_3 was carried out on 7th May, 2020 (25th Baisakh, 2077) when berries were approximately 4 to 5 mm in size (berries pepper corn size stage, bunches tending downwards; E-L 29 stage) (Coombe and Dry, 2004). The second application of GA_3 was carried out after a week of the first application on 15th May, 2020 (2nd Jestha, 2077). GA_3 was sprayed all over the selected grape bunches until the surface flow was noticed from bunches, by using fine nozzle of knapsack sprayer. Vine management practices were performed as standards followed by WTHC, Kirtipur, Kathmandu, Nepal. The quantitative and qualitative attributes were observed after single harvesting of the grape bunches on 6th July, 2020 (22nd Ashad, 2077). Ten grape bunches were selected randomly from each experimental unit for measurement of fruit quality parameters. Further, 10 berries (4 from top section, 4 from middle section and 2 from bottom section) were randomly picked from each bunch for parameters observation (May, 2004). For quantitative observation, berry diameter, berry weight, berry volume, bunch weight, bunch length and yield attributes were recorded. Bunch color, juice pH, Total Soluble Solid (TSS), Titratable Acidity (TA) and TSS/TA ratio were assessed for qualitative observation. Bunch color was analysed by image analysis of each bunch through 'ImageJ' software that identified the change in coloration of grape bunches and estimated area of light green region on grape bunches that signified veraison or maturity. Statistical analysis was performed by using data analysis tools like R Stat 4.0.4, GEN Stat (18th edition) etc. The data were subjected to Analysis of Variance (ANOVA), mean separation by Duncan Multiple Range Test (DMRT) at 5% level of significance, dispersion, correlation and regression analysis.

RESULTS AND DISCUSSIONS

BERRY AND BUNCH CHARACTERISTICS

Berry characteristics such as berry diameter, berry weight and berry volume; and bunch characteristics including bunch weight and bunch length were found substantially different between the treatments, recorded at harvest (Table 1, Figure 1).

Table 1. Effect of GA_3 on berry and bunch characteristics (Mean ± SEM) of grapevine var. Himrod in WTHC, Kirtipur, Kathmandu, Nepal, 2020.

Conc. of GA_3	Berry diameter (mm)	10 berry weight (g)	10 berry volume (ml)	Bunch weight (g)	Bunch length (cm)
10 ppm	16.88^{b}±0.29	30.55^{b}±1.48	29.35^{b}±1.19	400.68^{a}±36.36	20.35^{a}±0.63
20 ppm	17.63^{a}±0.25	34.93^{ab}±1.34	33.70^{a}±1.01	391.23^{a}±35.71	19.40^{ab}±0.34
30 ppm	17.90^{a}±0.11	36.22^{a}±0.84	34.88^{a}±1.04	364.89^{a}±52.54	19.47^{ab}±0.78
40 ppm	18.23^{a}±0.37	37.73^{a}±2.43	36.05^{a}±2.54	408.73^{a}±29.95	19.55^{ab}±0.45
Control	15.71^{c}±0.25	24.43^{c}±1.40	23.48^{c}±0.89	258.53^{b}±24.37	18.10^{b}±0.23
Grand mean	17.27	32.77	31.49	364.81	19.37
LSD	0.726***	4.589***	4.230***	61.34***	1.394*
CV (%)	2.7	9.1	8.7	10.9	4.7

Means followed by common letter(s) within a column do not differ significantly at ≤5 % level of significance by DMRT; LSD = Least significant difference; significance codes ***at p≤0.001; **at p≤0.01; *at p≤0.05; SEM = Standard error of mean; CV = Coefficient of variation.

Berry diameter, berry weight and berry volume were found to be increased with increasing concentrations of GA_3, the maximum at 40 ppm and the minimum in control treatment (Table 1). In cultivars like 'Thompson Seedless' and 'Flame Seedless', GA_3 application from 10 to 50 ppm concentrations caused significant increase in berry physical characteristics like width, weight, and volume (Dokoozlian *et al.*, 2001; Elgendy *et al.*, 2012; Marzouk and Kassem, 2011; Reynolds and Savigny, 2004). The presented data was identical with the results reported that frequent application of GA_3 had increased the berry width and berry weight on cv. Thompson Seedless (Fallahi *et al.*, 1995; Hussein *et al.*, 1998), 'Flame Seedless' (Marzouk and Kassem, 2002; Shehata and El-Barbary, 1996), 'Ruby Seedless' (Omar and El-Morsy, 2000) and several other grape cultivars (Ben-Arie *et al.*, 1997; Dokoozlian and Peacock, 2001). Miyoshi *et al.* (1997) stated identical results that 50 ppm of GA_3 application at full bloom stage had considerably increased berry weight by 20% in var. Himrod in Kirtipur, Kathmandu, Nepal. GA_3 was supposed to have stimulating effect on cell elongation process (Lee and Han, 2004; Sachs and Weaver, 1968; Taiz and Zeiger, 1991) and biosynthesis of protein thereby, development of strong sink causing increment in water uptake followed by solute storage (Hale and Weaver, 1962; Zhenming*et al.*, 2008) thus, causing enhancement on berry dimensions (Elgendy *et al.*, 2012).

0 ppm of GA_3 (Control) | 10 ppm of GA_3 | 20 ppm of GA_3 | 30 ppm of GA_3 | 40 ppm of GA_3

Figure 1. Images showing the differences in bunch architecture and berry sizes treated with different concentrations of GA_3 in WTHC, Kirtipur, Kathmandu, Nepal

Among the tested treatments, 40 ppm of GA_3 gave the highest bunch weight while the lowest was obtained in the control treatment. With respect to bunch length, there was no significant difference observed among the GA_3 treatments expect the control treatment. The lowest bunch length was obtained in the control treatment. In cultivars like 'Thompson Seedless' and 'Flame Seedless', GA_3 application from 10 to 40 ppm concentrations caused significant increase in bunch weight (Abd El-Wahab, 2006; Elgendy *et al.*, 2012; Navarro *et al.*, 2001). The increase in bunch weight was due to increase in berry weight and size by GA_3 treatment that caused acceleration on synthesis of carbohydrates and proteins thereby, more availability and mobilization of organic nutrients towards the bunches (Elgendy *et al.*, 2012). In case of bunch length, the obtained result was identical with research study by Lee and Han (2004) which mentioned that bunch length only varied significantly between the GA_3 treated and the control bunches in var. Kyoho.

YIELD ATTRIBUTES

There was substantial difference in bunch weights per vine between the treated and the control treatments, the maximum in 40 ppm of GA_3 and the minimum in control treatment (Table 2). Vines treated with 28 ppm of GA_3 resulted in higher yield in var. Thompson Seedless which was due to increment in berry and bunch weight by GA_3 application (Marzouk and Kassem, 2011). The bunch number per vine and potential yield per vine remained unaffected by the treatment application. There was large variation in bunch number per vine, as the grapevines of different age group were selected for treatment application due to fewer grapevines number in the research center. Also, only 10 bunches per vine were selected for treatment application, thus, the treatment difference was not that large enough to show the umbrella effect for a whole vine yield. Dokoozlian and Peacock (2001) mentioned similar results that bunch weight, yield per vine were not affected by 2 g/ha GA_3 treatments at different stages of bloom in cv. Crimson Seedless.

Table 2. Effect of GA_3 on yield and yield attributing characteristics (Mean ± SEM) of grapevine var. Himrod in WTHC, Kirtipur, Kathmandu, Nepal, 2020.

Conc. of GA_3	10 Bunch weight (kg/vine)	Bunch number (per vine)	Potential yield (kg/vine)
10 ppm	4.01^{a}±0.36	119±55 (5.45)	53.31±27.89 (4.52)
20 ppm	3.91^{a}±0.36	76±41 (4.93)	32.44±19.31 (3.98)
30 ppm	3.65^{a}±0.53	76±41(4.79)	30.77±16.59 (3.75)
40 ppm	4.09^{a}±0.30	56±14 (4.86)	23.27±6.88 (3.95)
Control	2.59^{b}±0.24	64±34 (4.84)	18.91±11.71 (3.48)
Grand mean	3.65	78 (4.97)	31.74 (3.93)
LSD	0.613***	98 $(1.136)^{ns}$	45.45 $(1.263)^{ns}$
CV (%)	10.9	81.5 (14.8)	92.9 (20.8)

Means followed by common letter(s) within a column do not differ significantly at ≤5 % level of significance by DMRT; LSD = Least significant difference; significance codes ***at p≤0.001; **at p≤0.01; *at p≤0.05; ns = non-significant; SEM = Standard error of mean; CV = Coefficient of variation. The numbers in parenthesis indicated (log x + 1) value to compensate the large difference among the treatments.

BERRY QUALITY ATTRIBUTES

In relation to bunch color, GA_3 treated bunches showed significantly higher area of light green region on bunches in comparison to the control treatment (Table 3), suggesting GA_3 promoted the maturity of grape berries (Abu-Zahra, 2010). Some variations were obtained in pH and TSS for grape juice, but both pH and TSS for different treatments did not varied significantly. However, the least pH and TSS values were obtained for the control grape berries. In case of TA and TSS/TA ratio, treated grape berries varied significantly from that of the control treatment, observing the maximum TA and minimum TSS/TA ratio in the control treatment as the juice contained the highest amount of organic acids among all the treatments.

GA_3 applied during or after flowering has resulted in higher color uniformity and early ripening of the berries (Marzouk and Kassem, 2002; Prasad and Pathak, 1975). GA_3 has been said to hasten the maturity of grape berries by affecting the berry qualities such as decreasing the TA content (Abu-Zahra, 2010). Avenant and Avenant (2005) had mentioned similar results that no significant difference in pH by GA_3 treatment in var. Red Globe. Lee and Han (2004) and Lee *et al*. (1997) stated that GA_3 treatment had very little effect on quality parameters thus, in GA_3 applied grape bunches, TSS was found to be equal or above in comparison to that of the control in var. Thompson Seedless (Abu-Zahra, 2010; Harrell and Williams, 1987) which was identical with results in var. Himrod. The amount of TA was decreased by 50 ppm GA_3 application in var. Thompson Seedless (Abu-Zahra, 2010). In cultivars like 'Thompson seedless' and 'Flame seedless', increase in GA_3 concentration caused gradual increase in TSS but decrease in TA (Elgendy et al., 2012; Shaaban et al., 1989); and increment in TSS/TA ratio (Elgendy et al., 2012; Tambe, 2002).

Table 3. Effect of GA_3 on quality characteristics (Mean ± SEM) of grapevine var. Himrod in WTHC, Kirtipur, Kathmandu, Nepal, 2020.

Conc. of GA_3	Bunch color (cm^2)	pH	TSS (°Brix)	TA (%)	TSS/TA Ratio
10 ppm	26.96^{a}±2.47	3.26±0.01	15.20±0.37	0.7345^{ab}±0.0339	21.06^{ab}±0.95
20 ppm	30.81^{a}±2.03	3.25±0.04	15.32±0.35	0.7108^{ab}±0.0522	22.48^{b}±1.84
30 ppm	30.61^{a}±2.62	3.26±0.04	15.12±0.63	0.6510^{b}±0.0421	23.50^{b}±2.14
40 ppm	25.46^{ab}±2.20	3.24±0.05	14.81±0.69	0.6849^{b}±0.0542	22.59^{b}±2.23
Control	20.30^{b}±1.29	3.12±0.04	14.72±1.03	0.8198^{a}±0.0759	18.43^{a}±2.02
Grand mean	26.83	3.23	15.04	0.7202	21.61
LSD	6.580**	0.1187^{ns}	1.251^{ns}	0.1084*	3.479^{*}

Conc. of GA_3	Bunch color (cm^2)	pH	TSS (°Brix)	TA (%)	TSS/TA Ratio
CV (%)	32.1	2.4	5.4	9.8	10.4

Means followed by common letter(s) within a column do not differ significantly at ≤5 % level of significance by DMRT; LSD = Least significant difference; significance codes ***at p≤0.001; **at p≤0.01; *at p≤0.05; ns = non-significant; SEM = Standard error of mean; CV = Coefficient of variation.

RELATIONSHIP BETWEEN YIELD ATTRIBUTES

Berry diameter, berry weight, berry volume and bunch weight were found to be positively correlated but had negative correlation with TA (Table 4). Abu-Zahra (2010) reported the berry diameter had significant positive correlation with berry weight, bunch weight and bunch length in var. Thompson Seedless.

Table 4. Correlation coefficients between measured parameters of grapevine var. Himrod in WTHC, Kirtipur, Kathmandu, Nepal, 2020.

	Berry diameter	10 berry width	10 berry volume	Bunch weight	Bunch length	PH	TSS	TA(%)	TSS/TA
Berry diameter	1								
10 berry width	0.9762	1							
10 berry volume	0.9589	0.9726	1						
Bunch weight	0.3926	0.3810	0.3736	1					
Bunch length	0.0562	0.0442	0.0102	0.5832	1				
PH	0.4522	0.4551	0.4182	0.3906	0.1573	1			
TSS	0.1899	0.1813	0.1430	0.2039	0.0608	0.576	1		
TA(%)	-0.4474	-0.4189	-0.4059	-0.3229	-0.0805	-0.434	-0.3141	1	
TSS/TA	0.4384	0.4108	0.3811	0.3148	0.0725	0.602	0.6072	-0.8903	1

As shown in Figure 2, 95.29% variation in berry weight was explained by berry diameter showing direct relationship. Hence, the effect of GA_3 on berry diameter had significant impact on berry weight and thus in berry yield.

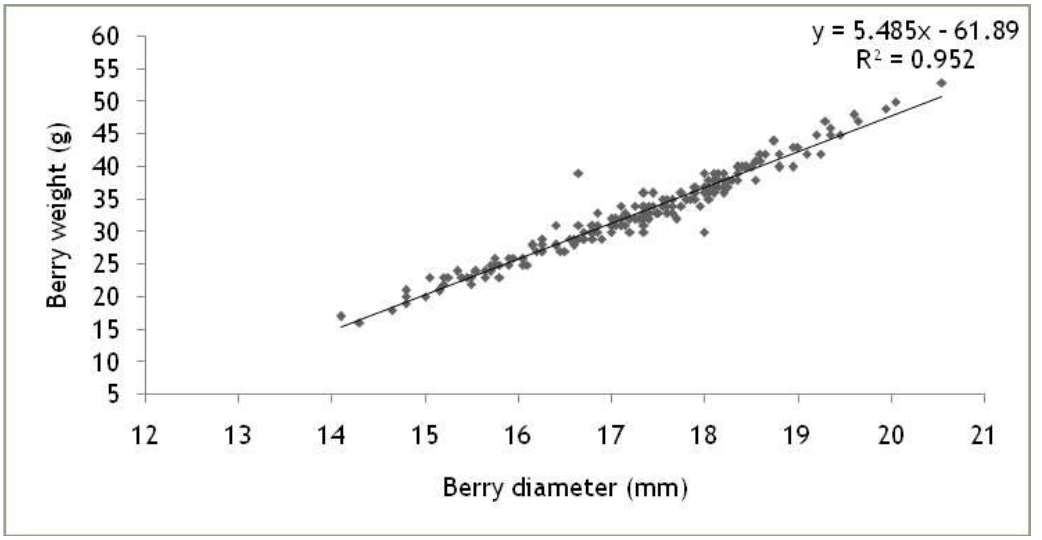

Figure 2. Linear regression showing the berry weight relation to berry diameter in WTHC, Kirtipur, Kathmandu, Nepal, 2020

On the basis of coefficient of determination (R^2), it was found that 79.06% variation in potential yield per vine was due to bunch number, while 57.20% variation in the potential yield per vine was explained by bunch weight. The potential yield per vine is the product of bunch number and bunch weight, hence GA_3 treatment was responsible for increase in bunch weight and thus in bunch yield. The qualitative observations, TSS and TA were negatively correlated. Similar result was obtained in research conducted by Bhullar and Dhillon (1977). TA values were correspondingly decreased with the increasing values of berry diameter. Richard (2006) reported GA_3 encourages growth by increasing plasticity of the cell wall followed by hydrolysis of starch into sugars which decreases the cell water potential thus, allowing entry of water in the cell that causes dilution of titratable acids as well as promotes cell elongation.

CONCLUSIONS

The yield attributes such as berry size, berry weight, berry volume, bunch weight and berry color were increased significantly in the GA_3 treated bunches compared to the control in Himrod variety of grapevine. However, the quality parameters did not differ significantly among the GA_3 treatments. TA was decreased significantly in GA_3 treated berries. The effect of GA_3 on berry diameter had significant impact on berry weight and berry volume, and thus in yield. This experiment was limited to application of GA_3 on bunches thus, further GA_3 applications is suggested in the whole grapevine, concerning variety, doses and number of GA_3 applications.

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PRECISION NITROGEN MANAGEMENT IN WHEAT AT RAMPUR, CHITWAN, NEPAL

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ABSTRACT

The application of blanket recommendation of nitrogen fertilizer leads to over or under fertilization. There is need to synchronize the N fertilizer application with plant demand. Field experiment was conducted during 2019 -2020 in Chitwan to assess the yield, nitrogen use efficiencies and economics of wheat production under precision N management compared with fixed time N management. Experiment was laid out in split plot design with sixteen treatments and three replications. The main plot treatments were varieties Vijay and Banganga and subplot treatments were three SPAD readings (≤35, ≤40, ≤45), two LCC readings (≤4, ≤5), Nutrient expert tool, fixed time nitrogen management(FTNM) with national recommended dose and control (zero N). The research result showed that varieties did not differ in yield and economics. Precision nitrogen management with SPAD≤45 and LCC≤5 consumed higher nitrogen doses and produced better yield attributes and yield (5585 and 5385 kgha^{-1} respectively) compared with FTNM. The agronomic use efficiency of nitrogen (AEN), recovery efficiency (REN), partial factor productivity (PFP were highest at LCC≤4 which consumed less nitrogen. SPAD≤35, LCC≤4 and NE treatments saved 15, 35 and 20 kgha^{-1} N respectively without compromising the yield obtained in FTNM. But, the benefit: cost ratio was highest at LCC≤5.Therefore, in terms of yield and profitability of wheat production, LCC≤5 is better than other treatments. The present national recommended dose of nitrogen to wheat crop is insufficient to achieve higher yield in Chitwan condition.

Key words: Agronomic efficiency of nitrogen (AEN), fixed time nitrogen management (FTNM), leaf color chart (LCC), NE (Nutrient Expert tool), partial factor productivity (PFP), recovery efficiency of nitrogen (REN), soil plant analysis development (SPAD)

INTRODUCTION

Wheat is one of the most important cereal crops in Nepal after rice and maize. It is cultivated in 0.7 million ha land with production of 2.1 million mt (MoALD, 2021). It is consumed as staple food by 36 % of the world population (Mohanty *et al.*, 2015). It is predicted that 50-70% more cereal grains will be required to feed 9.3 billion people by 2050 (Ladha *et al.,* 2005).

Nitrogen Fertilizer is an important agricultural input that contributes to the final yield of crop. The improper and inadequate use of fertilizers is one of the reasons of

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low productivity of wheat in Nepal (Bhatta *et al., 2020)*. Nitrogen fertilizer is generally managed by following the blanket or standard recommendations in developing countries like Nepal (Ladha *et al.*, 2005). Blanket fertilizer recommendation does not consider the spatial and temporal variation of crop demand to fertilizer leading to low fertilizer use efficiency, environmental pollution and higher cost of cultivation (Ghosh *et al.,* 2018).

The synchronization of Nitrogen fertilizer application with plant demand is necessary to reduce the losses, optimize the nutrient use efficiency and minimize the environmental pollution (Dineshkumar *et al.,* 2013). This could be done with the help of precision N management practices.

Precision nitrogen management is based on the principle of 4 'R's applying the right rate, at right time, in the right place, using the right source and balance (Chaudhary *et al.*, 2019). Precision nitrogen management uses various tools and technologies such as LCC, SPAD, green-seeker, nutrient expert model, crop simulation model etc. for gathering information about spatial and temporal differences within the field in order to match inputs according to site-specific field conditions (Diacono et al., 2013).

The LCC and SPAD meter can be used to monitor plant N status in the field and determine the right time of nitrogen top dressing in the crop (Doberman and Fairhurst, 2000) at right physiological stage of nutrient demand (Majumdar *et al.*, 2013). Nitrogen management with LCC and SPAD facilitates the saving of nitrogen without yield reduction and improves N use efficiency (Barad*et al.,* 2018). Research works on precision nitrogen management in wheat crops are very limited in Nepal as most of the works are concentrated towards rice. Therefore, the present study is conducted with the objectives to determine the growth and productivity of wheat at conventional and precision N management, to the N use efficiencies of wheat at conventional and precision N management and to work out the economics of conventional and precision N management.

METHODOLOGY

The research was conducted in agronomy farm of Agriculture and Forestry University (AFU), Rampur, Chitwan, Nepal starting from November 2019 to April 2020. It is located at $27^0 40^{'}$ North latitude and $84^0 23^{'}$ East longitude and 9.8 km South-west from Bharatpur Metropolitan city, the headquarter of Chitwan district. The soil of experimental site was sandy loam, acidic in pH (5.64), medium in organic matter (3.07%) and total Nitrogen (0.15%) and lower in $P_2 0_5$ (22.04 $kgha^{-1}$) and $K_2 0$ (80.04 $kgha^{-1}$). Average maximum temperature ranged from 25^0C to 27^0C and average minimum temperature ranged from 14.05^0C to 23.3^0C during the experimental period. The average relative humidity and rainfall was 84.94% and 5.30 mm respectively. These data were recorded by metrological station of NMRP, Rampur Chitwan.

The experiment was laid out in split plot design with the total of 16 treatments i.e., two varieties (Vijay and Banganga) as main factor and eight N management in subplot factor as follows.

T1 = Control (0 $kgha^{-1}$ Nitrogen)
T2= 40 $kgha^{-1}$ N basal + 30 $kgha^{-1}$ N when SPAD reading showed 35 or less
T3 = 40 $kgha^{-1}$ N basal + 30 $kgha^{-1}$ N when SPAD reading showed 45 or less
T4= 40 $kgha^{-1}$ N basal + 30 $kgha^{-1}$ N when LCC reading showed 5 or less
T5 = Nutrient Expert Tool (Software used to calculate N requirement)
T6 = 40 $kgha^{-1}$N basal + 30 $kgha^{-1}$ when SPAD reading showed 40 or less
T7 = 100 $kgha^{-1}$N, 40 $kgha^{-1}$ N basal application+ top dressing at CRI and at Tillering
T8 = 40 $kgha^{-1}$ N basal + 30 $kgha^{-1}$ N when LCC reading showed 4 or less

The treatments were replicated thrice and there were total of 48 plots. Each individual plot had 12 rows with the spacing of 25cm apart with plot of 3m×2.5m (7.5m^2.) The spacing between plots was 0.5 m and the spacing between replications was 1.5 m. The line sowing was done with the spacing of 25 cm and continuous seed placement within rows.

The National Recommended Dose (NRD) of fertilizer i.e., 100:50:25 N, P_2O_5 and K_2O $kgha^{-1}$ (MoALD, 2019) was applied through the urea, Single Super Phosphate (SSP) and Muriate of Potash (MoP) respectively. Full dose of phosphorus (SSP) and potash was applied as basal dose at the time of sowing. 40 kg Nha^{-1} was applied as the basal dose and remaining Nitrogen fertilizer was applied as per the treatment guided by LCC and SPAD. However, on Nutrient Expert (NE) 26 $kgha^{-1}$ N was applied as basal dose.
Both LCC and SPAD readings were taken at 21 days after sowing till flowering at the interval of 10 days during morning time 8-10 am. The reading was taken from topmost fully expanded leaf of 10 healthy plants.

Effective tillers per square meter

Before harvesting, effective tillers per square meter were determined by counting total number of tillers bearing spike from the row length of 2.5m.

Number of grains per spike

Twenty spikes from net plot area were randomly selected. The total no of grains per spike were calculated from each spike and mean were calculated.

Sterility percentage

$$\text{Sterility percentage} = \frac{\text{Total number of florets per spike} - \text{number of grain per spike}}{\text{Total number of grain per spike}} \times 100$$

Thousand grain weight

Thousand grain weight of wheat from each net plot was recorded and expressed in 12% moisture level.

Grain yield

$$\text{Grain yield kg ha}^{-1}\text{ at 12\% moisture} = \frac{(100 - \text{MC}) \times \text{plot yield(kg)} \times 10000}{(100 - 12) \times \text{net plot area}}$$

Agronomic Use Efficiency (AEN) (Dobermann, 2007)

$$\text{Agronomic Efficieny} = \frac{\text{Grain yield in N fertilized plot} - \text{Grain yield in no N plot}}{\text{Quantity of N applied in N fertilized plot}}$$

Recovery Efficiency (REN) (Dobermann, 2007)

$$\text{Recovery Efficieny} = \frac{\text{Total N uptake in N fertilized plot} - \text{Total N uptake in no N plot}}{\text{Quantity of N applied in N fertilized plot}}$$

Partial Factor Productivity (PFP) (Dobermann, 2007)

$$\text{PFP} = \frac{\text{Grain yield } (kg\ ha^{-1})}{\text{Total amount of Nitrogen applied (kg } ha^{-1})}$$

RESULTS AND DISCUSSIONS

TOTAL NITROGEN APPLIED

The amount of nitrogen applied in the variety Vijay was (108.75 kgha^{-1}) significantly higher than Banganga (Table 1). The highest amount of N (215 kgha^{-1}) was used with SPAD≤45 followed by LCC≤5 (165 kgha^{-1}) (Table1).There was saving of 15, 35 and 20 kgha^{-1} nitrogen respectively under SPAD≤35, LCC≤4 and NE compared with FTNM. Saving of Nitrogen under the LCC and SPAD guided nitrogen compared to FTNM in wheat was also observed by Reena *et al*. (2017) and Baral *et al*. (2019).

Table 1. Total nitrogen applied in wheat as influenced by precision N management and varieties at Rampur, Chitwan, 2019-2020

Treatments	Total N applied (kgha^{-1})	N saving/ excess
Varieties		
Vijay	108.75[a]	-7.25
Banganga	100[b]	0
SEm (±)	4.375	
LSD (0.05)	5.37	
CV (%)	4.1	

Treatments	Total N applied (kgha^{-1})	N saving/ excess
Nitrogen management		
Control	0^{f}	
SPAD≤35	85de	+15
SPAD≤40	125^{c}	-25
SPAD≤45	215^{a}	-115
LCC ≤4	65^{f}	+35
LCC ≤5	165^{b}	-65
NE	80^{ef}	+20
FTNM	100^{d}	0
SEm (±)	23.09	
LSD (0.05)	15.84	
CV (%)	12.9	
Grand mean	104	-4

Note: Figure(+) indicates the N saving and (-) indicates the excess of N in kgha^{-1} as compared with fixed time N management RDF (100 kg Nha^{-1}). FTNM, fixed time splitting government recommended dose (100 kg N ha^{-1}); NE nutrient expert, (80 kg Nha^{-1}); SPAD ≤35, 30 kg Nha^{-1} when SPAD reading less than or equal to Nha35 (85kg Nha-1); SPAD≤ 40, 30 kg Nha^{-1} when SPAD reading less than or equal to 40 (125kg Nha^{-1}); SPAD≤45 30 kg Nha^{-1} when SPAD reading less than or equal to 45 (215 kg Nha^{-1}); LCC ≤ 4 , 30 kg Nha^{-1} when LCC reading less than or equal to 4 (65 kg Nha^{-1}); LCC ≤5, 30 kg Nha^{-1} when LCC reading less than or equal to 5 (165 kg Nha^{-1}); SPAD, soil plant analysis development ; LCC, leaf color chart. Treatments means followed common letter(s) are not significantly different among each other based on DMRT at 5% level of significance.

The saving of N might be due to better synchronization of N fertilizer application with crop demand that led to increased nitrogen uptake, recovery efficiency and decreased volatilization and denitrification (Maiti and Das, 2006). However, there was no saving of N at SPAD and LCC at their higher threshold (40, 45 and 5). It indicated that the wheat was underfed in FTNM with national recommended dose, SPAD≤35, LCC≤4 and NE treatments.

YIELD ATTRIBUTES

Effective tillers

Higher number of effective tillers per meter square was recorded with SPAD≤45 and LCC≤5 and lower was observed with control (Table 2). The number of effective tillers m^{-2} found increasing with increasing nitrogen doses and number of splits. It might be due to higher availability of nitrogen at tiller forming stage of crop and reduction in tiller mortality (Rahman *et al.*, 2014). Yousaf *et al.* (2014) also reported higher number of effective tillers m^{-2} under the higher nitrogen doses. Increasing number of effective tiller m^{-2} with increasing number of split applications of N compared with single and double split was also reported by Bhardwaj *et al.* (2010).

Spike length

The higher spike length was recorded with SPAD≤45, LCC≤5 which were statistically at par with SPAD≤40. The smallest spike was on control plot. Length of spike found increasing with increasing nitrogen doses. Rai and Khadka (2009) also reported linear increase of spike length with nitrogen doses.

Grains per Spike

Banganga variety had significantly higher number of grains per spike (38.0) than Vijay (31). It might be due to differences in their genotypic character. Schwarte *et al.* (2006) reported that the number of grains per spike were strongly dependent on genetic factors rather than management factors. The number grains per spike were also found increasing with nitrogen doses and number of splits. Higher numbers of grains per spike were recorded on LCC≤5 which was statistically at par with SPAD≤45 and SPAD≤40 (Table 2). The lowest grains per spike were in control. Iqbal *et al.* (2012) also reported higher number grains per spike at higher N doses and lowest at control.

Sterility percentage

The sterility percent (46.4%) was found highest in control and it did not differ among all other nitrogen applied treatments (Table 2). Kataki *et al.* (2001) also reported that application of N did not have influence on wheat sterility with increasing doses of nitrogen from 16-160 kg Nha^{-1}.

Thousand grain weight

The thousand grain weight was observed higher in SPAD≤45 (58.81g) which was statistically at par with SPAD≤40, LCC≤5, LCC≤4 and NE (Table 2). All the treatments produced significantly higher thousand grain weight over control where no nitrogen was applied. It might be due to the better nutritional status of plant resulting in improvement on grain filling and development (Woyema *et al.* 2012). Similar results were also reported by Yousaf *et al.* (2014).

Table 2. Effective tiller, spike length, grains per spike, sterility percentage, thousand grain weight and grain yield as influenced by precision N management and varieties at Rampur, Chitwan, 2019-2020

Treatments	Effective tiller m^{-2}	Spike length (cm)	Sterility percentage	Grains per Spike	Thousand grains weight (g)	Grain yield ($kgha^{-1}$)
Varieties						
Vijay	238	15.15	36.1	31.9[b]	56.58	4029.79
Banganga	247	15.93	36.0	38.0[a]	55.94	4088.49

SEm (±)	4.33	0.39	0.04	3.04	0.32	29.00
LSD (0.05)	Ns	Ns	Ns	1.99	Ns	Ns
CV (%)	12.9	5.4	5	4.6	2.8	4.60
Nitrogen management						
Control	175^{c}	11.15^{d}	46.4^{a}	13.4^{d}	49.15^{c}	932.26^{d}
SPAD≤35	223^{b}	15.86^{bc}	34.8^{b}	35.5^{c}	56.34^{b}	3963.55^{c}
SPAD≤40	267^{ab}	16.60^{ab}	30.3^{b}	40.4^{ab}	56.74^{ab}	4807.67^{b}
SPAD≤45	283^{a}	16.83^{a}	37.5^{b}	40.0^{ab}	58.81^{a}	5585.00^{a}
LCC≤4	242^{ab}	15.43^{c}	32.3^{b}	35.8^{c}	57.81^{ab}	3869.12^{c}
LCC ≤5	275^{a}	16.83^{a}	34.0^{b}	43.0^{a}	57.10^{ab}	5385.00^{ab}
NE	225^{b}	15.80^{bc}	36.3^{b}	34.5^{c}	57.60^{ab}	3882.29^{c}
FTNM	251^{ab}	15.80^{bc}	36.6^{b}	37.3^{bc}	56.47^{b}	4047.67^{c}
SEm (±)	12.38	0.65	1.70	3.25	1.04	508
LSD (0.05)	41.33	0.79	7.36	3.22	1.52	405.87
CV (%)	14.4	4.3	17.3	7.8	3.1	12.7
Grand mean	243	15.54	36.0	35.0	56.26	4059

Note: FTNM, fixed time splitting government recommended dose (100kg Nha^{-1}); NE nutrient expert, (80kg Nha^{-1}); SPAD ≤35, 30 kg Nha^{-1} when SPAD reading less than or equal to 35 (85kg Nha^{-1}); SPAD≤ 40, 30 kg Nha^{-1} when SPAD reading less than or equal to 40 (125kg Nha^{-1}); SPAD≤45 30 kg Nha^{-1} when SPAD reading less than or equal to 45 (215kg Nha^{-1}); LCC ≤ 4 , 30 kg Nha^{-1} when LCC reading less than or equal to 4 (65kg Nha^{-1}); LCC ≤5, 30 kg Nha^{-1} when LCC reading less than or equal to 5(165 kg Nha^{-1}); SPAD, soil plant analysis development ; LCC, leaf color chart .Treatments means followed common letter (s) are not significantly different among each other based on DMRT at 5% level of significance.

GRAIN YIELD

The highest yield was observed with nitrogen application at SPAD≤45 (5585 kgha^{-1}) which was statistically at par with LCC≤5 but higher than SPAD≤40 (Table 2). The lowest yield was observed in control. Higher yield with SPAD≤45 and LCC≤5 was due to higher nitrogen doses (215 kgha^{-1} and 165 kgha^{-1}). This condition might have contributed to the availability of nitrogen at the later stages of the crop growth. Singh *et al*. (2013) reported that late season N supply contribute to the higher grain yield. Grain yield obtained in FTNM was statistically at par with LCC≤4, SPAD≤35 and NE respectively however, these treatments consumed less nitrogen compared with FTNM. This might be due to the better synchronization of N supply with crop N demand starting from vegetative growth to reproductive growth of crop. This led to increase in photosynthesis rate resulting to the higher growth and biomass production (Reena *et al.*, 2018). Higher yield under LCC≤5 compared with LCC≤4 was also reported by Dineshkumar *et al*. (2013), Maiti and Das (2006) and Singh *et al*. (2012). The increased grain yield with LCC<5 over other levels was associated with significant increase in yield components such as effective tillers m^{-2}, number of grains per spike and 1000-grain weight (Dineskhkumar *et al.*, 2013). Our results did not match with Ghosh *et al*. (2018) and Barad *et al*. (2018) who observed SPAD≤40 as better nitrogen management option for wheat in India.

NITROGEN USE EFFICIENCIES

The highest AEN found with nitrogen application at LCC≤4 (37.39 kgkg^{-1}) which was statistically at par with other treatments except SPAD≤45 and LCC≤5 in which higher nitrogen was applied (Table 3). AEN found decreasing with increasing nitrogen doses. The lower AEN with SPAD≤45 and LCC≤5might be due to the application of N at later stages of crop growth. Singh *et al.* (2012) reported that N applied after maximum tillering growth stages might not improve the AEN. Higher AEN under LCC and SPAD at their lower threshold (4, 35 and 40) and NE might be due to timely availability of N for their better utilization by the plant (Reena *et al.*, 2018). It might also be due to increased uptake and reduced loss of Nitrogen (Frageria and Balighar, 2005). Ghosh *et al.* (2018) reported that SPAD based nitrogen management increased AEN by 58.5% over FTNM. Shukla *et al.* (2004) observed higher AEN under LCC≤4 than LCC≤5.The AEN value ranged from 18.57-37.39 kgkg-^{1} in this research. Doberman (2005) stated AEN range for cereal crops lies between 10-30 kgkg^{-1}. More than 30 kgkg^{-1}AEN indicates the well managed systems or low level of N use or low soil N supply.

The higher REN was found with nitrogen application at LCC≤4 (79.54%) which was statistically at par with all other nitrogen applied treatments except SPAD≤45 (Table 3). The lowest recovery efficiency was with SPAD≤45. It might be due to the application of higher doses of N exceeding the crop demand (Baral *et al.*, 2021). The recovery efficiency ranged from 61.17-79.54 %. According to Dobermann (2005), the recovery efficiency values for wheat in a well-managed system ranged between 50-80%. The recovery efficiency of LCC≤4 was 79%. It might be due to low levels of nitrogen use. The increase in AEN and REN with lower amount of nitrogen was associated with increase in grain yield with less nitrogen compared with that of high amount of nitrogen application (Ghosh *et al.*, 2018). The PFP was found highest with nitrogen application at LCC≤4 which was statistically at par with SPAD≤35. The PFP was also found decreasing with increasing nitrogen doses. It might be due to higher values of nitrogen dose on denominator compared with numerator and also due to diminishing law of marginal utility. Similar trend was also observed by Rawal *et al.* (2022).

Table 3. Agronomic use efficiency, recovery efficiency and partial factor productivity as influenced by precision N management and varieties at Rampur, Chitwan, 2019-2020

Treatments	AEN (kgkg^{-1})	REN (%)	PFP(kgkg^{-1})
Varieties			
Vijay	25.66	68.28	34
Banganga	31.91	65.39	39
SEm (±)	2.42	0.01	2.79
LSD (0.05)	Ns	Ns	Ns
CV (%)	56.4	29.8	21.3

Treatments	AEN (kgkg^{-1})	REN (%)	PFP(kgkg^{-1})
Nitrogen management			
Control	0.00	0.00	0.00
SPAD≤35	32.27^{ab}	62.95^{ab}	48.00^{ab}
SPAD≤40	26.44^{abc}	65.08^{ab}	41.63^{bc}
SPAD≤45	18.57^{c}	61.17^{b}	24.58^{d}
LCC≤4	37.39^{a}	79.54^{a}	62.74^{a}
LCC ≤5	23.74^{bc}	69.16^{ab}	31.38^{cd}
NE	32.45^{ab}	67.31^{ab}	46.22^{bc}
FTNM	27.42^{abc}	62.47^{b}	39.39^{bc}
SEm (±)	2.361	0.017	6.60
LSD (0.05)	10.44	15.20	13.67
CV (%)	33.91	18.9	31.4
Grand mean	29.88	67.2	36.79

Note: FTNM, fixed time splitting government recommended dose (100 kg Nha^{-1}); NE nutrient expert, (80 kg Nha^{-1}); SPAD ≤35, 30 kg Nha^{-1} when SPAD reading less than or equal to 35(85kg Nha^{-1}); SPAD≤ 40, 30 kg Nha^{-1} when SPAD reading less than or equal to 40 (125kg Nha^{-1}); SPAD≤45 30 kg Nha^{-1} when SPAD reading less than or equal to 45(215 kg Nha^{-1}); LCC ≤ 4 , 30 kg Nha^{-1} when LCC reading less than or equal to 4 (65kg Nha^{-1}); LCC ≤5, 30 kg Nha^{-1} when LCC reading less than or equal to 5(165 kg Nha^{-1}); SPAD, soil plant analysis development ; LCC, leaf color chart .Treatments means followed common letter (s) are not significantly different among each other based on DMRT at 5% level of significance.

Benefit Cost Ratio (BCR)

The BCR was found highest in LCC≤5(2.0) which was statistically at par with SPAD≤45 and SPAD≤40 (Table 4). The net return was highest with nitrogen application at LCC≤5, SPAD≤45 and SPAD≤40. Kharel et al (2021) reported the BCR of wheat was 1.78 in inner terai of Nepal. However, it was found higher at higher nitrogen doses in this study. The total cost of cultivation varied because Vijay variety consumed higher nitrogen dose compared to Banganga.

Table 4. Cost of cultivation (NRs ha^{-1}), gross return (NRs ha^{-1}), net return (NRs ha^{-1}) and BCR as influenced by precision N management and varieties at Rampur, Chitwan, 2019-2020

Treatments	Total cost of cultivation (NRs ha^{-1})	Gross return (NRs ha^{-1})	Net return (NRs ha^{-1})	B:C R
Varieties				
Vijay	78562.36	128977.3	50414.84	1.64
Banganga	77344.21	131055.4	53710.66	1.69
SEm (±)	608	1039.03	647.91	0.03
LSD (0.05)	667.38	Ns	Ns	Ns
CV (%)	0.7	3.9	10.5	4.6
Nitrogen management				

Treatments	Total cost of cultivation (NRs ha^{-1})	Gross return (NRs ha^{-1})	Net return (NRs ha^{-1})	B:C R
Control	64708.50	30141.52^{d}	-34566.00^{c}	0.46^{c}
SPAD≤35	75147.63	127428.09^{c}	52280.20^{b}	1.69^{b}
SPAD≤40	80428.79	153531.57^{b}	73102.78^{a}	1.91^{ab}
SPAD≤45	92744.73	178436.71^{a}	85691.98^{a}	1.92^{ab}
LCC≤4	72573.72	124165.09^{c}	51591.38^{b}	1.70^{b}
LCC ≤5	85976.62	172434.98^{a}	86458.3^{a}	2.00^{a}
NE	74870.82	123941.65^{c}	49070.83^{b}	1.65^{b}
FTNM	77178.07	130051.26^{c}	52873.20^{b}	1.68^{b}
SEm (±)	3022.61	16229.19	13543.09	0.17
LSD (0.05)	3139.32	18820.88	18598.76	0.24
CV (%)	2.7	12.2	30.2	12.9
Grand mean	77953.28	130016.4	52062.75	1.63

Note: FTNM, fixed time splitting government recommended dose (100kg Nha^{-1}); NE nutrient expert, (80kg Nha^{-1}); SPAD ≤35, 30 kg Nha^{-1} when SPAD reading less than or equal to 35 (85kg Nha^{-1}); SPAD≤ 40, 30 kg Nha^{-1} when SPAD reading less than or equal to 40 (125kg Nha^{-1}); SPAD≤45 30 kg Nha^{-1} when SPAD reading less than or equal to 45(215kg Nha^{-1}); LCC ≤ 4 , 30 kg Nha^{-1} when LCC reading less than or equal to 4 (65kg Nha^{-1}); LCC ≤5, 30 kg Nha^{-1} when LCC reading less than or equal to 5(165 kg Nha^{-1}); SPAD, soil plant analysis development ; LCC, leaf color chart .Treatments means followed common letter (s) are not significantly different among each other based on DMRT at 5% level of significance

CONCLUSIONS

Higher yield of wheat with higher BCR and economic net return were recorded with the higher nitrogen application at LCC≤5. So, the present fixed time N application with national recommended dose is insufficient to achieve the high yield of wheat. There is need for revision of blanket recommendation of N fertilizer application in wheat as the crops are underfed. The nitrogen saving, AEN, REN, partial factor productivity found highest with a nitrogen application at LCC≤4 without compromising the yield loss as compared with FTNM.

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FIELD SCREENING OF ARABICA COFFEE GENOTYPES AGAINST COFFEE WHITE STEM BORER *(Xylotrechus quadripes)* AND LEAF RUST *(Hemileia vastatrix)* INFESTATION IN KASKI, NEPAL

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ABSTRACT

Twenty-three coffee (Coffea arabica) genotypes were evaluated for relative resistance against coffee white stem borer (Xylotrechus quadripes) and coffee leaf rust (Hemileia vastatrix) at Horticulture Research Station, Malepatan, Pokhara during three consecutive years from 2016 to 2019. The monthly observation on the emergence of this borer showed that coffee genotypes "Yellow caturra" and "Tekisic" were highly infested with coffee white stem borer as compared to the other genotypes. However, no infestation was observed in genotypes Catimor, San Ramon, Indo Tim-Tim, Ketisic, Pacas, Syangja special and both Vermelo and Amarillo groups in Catui and Caturra acessions. Similarly, genotypes Catimor, Indo Tim-Tim and San Ramon were determined to be resistant to coffee leaf rust. While coffee germplasm-Ketisic was also recorded as relatively resistant against coffee leaf rust. These results have important implications for the development of coffee white stem borer and leaf rust resistant high yielding coffee variety in the future.

Keywords: Germplasm, infestation, pest, resistance, scoring

INTRODUCTION

Coffea Arabica L. is the most disease and pest susceptible coffee species (Van der Vossen,2001). It's tetraploidy and autogamy nature combined with narrow genetic base multiplied through inbreeding would have led to genetic homogeneity (Lashermes *et al.*, 1996) and consequent vulnerability to pests (Anonymous, 1972). Within the *Coffea Arabica* species, natural hybrids are relatively scarce due to a high degree of self-pollination which is about 85-95%.*Coffeaarabica* is a self-compatible amphidiploid (2n=4x=44), whereas other *Coffea species* are diploid (2n=2x=22) (Lashermes *et al.*,1999).Comparatively larger genetic base of *Coffea robusta* under cultivation, primarily due to its obligate out-breeding nature and hence tolerance to pests (Ram *et al.*, 1994).So, the commercial coffee varieties have developed by crossing *Coffea arabica* and *Coffea robusta* using different plant breeding techniques.

Coffee white stem borer, *Xylotrechus quadripes* Chevrolat (Coleoptera: Cerambycidae) is a major pest in commercial plantations of coffee, *Coffea arabica*, in Nepal (Acharya & Dhakal, 2014).Immature grub bores to the plant usually attacks on

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the main stem and thick primary branches of *Coffea arabica* in severe case leads to death of the plant. Nearly 1 to 1.5 years of boring inside trunk, under favorable condition, it emerges as adult out of the trunk by making an exit hole (Gichuhi *et al.*, 2017).A study by National Entomology Research Center found that coffee white stem borer is number one threat causing yield loss up to 70% in Nepal (ED, 2007).Complete tolerance to this pest is not known to exist in *Coffea arabica*, but is much less prevalent on *Coffea robusta* and many other diploid species of coffee (Guerreiro-Filho, 2006).

Coffee leaf rust is new disease of coffee in Nepal. It was identified and reported by National Plant Pathology Research Center, Khumaltar, and Lalitpur, Nepal in April, 2015 (PPD, 2015). It is one of the serious challenges of coffee cultivation caused by the fungus *Hemileia vastatrix* Berk. It was a major problem in south Asia during late nineteenth century where it forced the abandonment of coffee production in large areas (McCook, 2006). Its infestation in the new world began in the 1980s (Fulton,1984) where it rapidly spread to all coffee growing areas but did not reached the devastating levels in earlier days in south Asia(Vandermeer*etal.*,2009).The basic biology of the coffee rust is weather dependent. The fungal spore 'uredospore' germinate within a drop of water on the underside of the leaf and penetrate the leaf through stomata, grow extensively in intercellular space forming a haustoria. Production of fruiting bodies on the underside of the leaf forming yellow rust texture which get spread by rain splash or wind to neighboring leaves and plants up to 150 km (Schieber,1972). It affects mainly matured leaves and on severe stage can also infect young leaves causing leaf drop results to loss in production. Normally, yield losses per year due to coffee rust range from 30 to 90% depending on the environmental conditions during a given year (Sera *et al*, 2005), especially if not controlled by fungicide spray. The economic damage to world Arabica coffee production due to coffee rust has been estimated to be between $(US) 1 billion and 2 billion per year (Van der Vossen, 2001) due to crop losses of 20–25% (Prakash *et al.*, 2004).

The gene S_H3 conditions resistance against coffee white stem borer and coffee leaf rust is believed to be transferred from *Coffea liberica* by a process of natural introgression (Rodrigues and Bettencourt, 1965).The plant Hibrido de Timor (HDT) is a todays' widely used leaf rust resistant donor genotype developed by crossing *Coffea arabica* with *Coffea robusta*(James *et.al.*, 2019). Catimor is the cross between Timor hybrid and Caturra accession; Catuai, the high yielding coffee resulting from a cross between Mundo Novo and Caturra;Mundo Novo, a natural hybrid between Typica coffee and Bourbon coffee and Bourbonamarillo and Bourbon vermelo are developed by the spontaneous mutation of coffee type Bourbon (WCR, 2016). Ketisicis also an improved Bourbon genotype (WCR, 2016).

The coffee production in Nepal is extensively organic in nature. So, farmers are not using any chemical pesticide, fungicide and weedicides. So, selection of coffee genotypes on the basis of susceptibility or tolerance to coffee white stem borer and coffee leaf rust is essential for varietal development and dissemination to farmers. Therefore, this study aims to assess the genotypes relative resistance to white stem borer and leaf rust which ultimately aids in the organic pest management.

METHODOLOGY

STUDY AREA

The present study was conducted in Horticulture Research Station, Malepatan, Pokhara, Nepal ($28^{O}13'$ N to $83^{O}58'$ E) from 2016 to 2019. The station lies in the elevation of 838-848 meter above average sea level (masl). The field experiments were done in thelitchi-coffee shade system planted at the ratio of 1:4. All intercultural operations and fertilizer application were done as per the recommendation.

SCREENING AGAINST COFFEE WHITE STEM BORER

Each variety of coffee have their own growth pattern i.e. branching and leaves pattern which determine the extent of stem exposure and hence to borer infestation. The coffee white stem borer surveillance was done in 23 coffee genotypes of 9 years' old each with 16 plants. The grub of beetle bores into the trunk from top to the bottom of the tree, boring near the surface makes characteristic bulging out of bark phloem tissue. During hot sunny days adult emerges out making a small circular hole from bark, each exit hole indicates the emergence of one adult specimen. The variety wise extent of infestation and damage by coffee white stem borer was recorded monthly from January, 2016 to December, 2018. Stems were thoroughly examined for stem bulging out or exit holes by white stem borer. The noted monthly data were averaged for further analysis and drawing conclusion.

SCREENING AGAINST COFFEE LEAF RUST

Twenty-three *Coffea arabica* L. accessions were evaluated for their response to coffee leaf rust under field conditions of HRS, Malepatan during the month of June during 2017 to 2019. The severity of leaf rust infestation was scored in numeric scale of 0 (most tolerant) to 9 (most susceptible)(Eskes and Toma-Braghini,1981). Scale value 0 indicates the absence of visible symptoms, 1 to 9 variation show the intensity of rust sporulation and damage. Coffee leaf rust infection was assessed from the 23 genotypes subjected to similar field conditions when disease pressure was at peak.

STATISTICAL ANALYSIS

The raw data were entered in MS-Excel, averaged and presented in bar diagram. The cluster analysis of coffee germplasms based on coffee white stem borer and coffee leaf rust infestation were done according to Ward (1963) in past.03 software. Cluster analysis was done to objectively divide the germplasms into groups based on number of sample plant infested using Euclidean distance paired group method. The cluster representation was done with dendrogram progressively dividing the accessions into smaller groups.

RESULTS AND DISCUSSIONS

VARIETAL SCREENING OF COFFEE AGAINST COFFEE WHITE STEM BORER

The given bar graph (Fig. 1) elucidates that among the twenty-three coffee genotypes evaluated for coffee white stem borer infestation, highest level of infestation (18.75%) was found in the coffee germplasms Yellow caturra and Tekisic followed by Arghakhachi local (12.5%). Ten genotypes namely Selection 10, Mundo Novo, Chhetradeep, Hawaii Kona, Pacamara, Kaski local, Indonesia, Bourbon amarillo, Bourbon vermeloand Puranchaur local showed same level of borer infestation (6.25%). While, remaining ten germplasms were observed to be free of coffee white stem borer infestation.

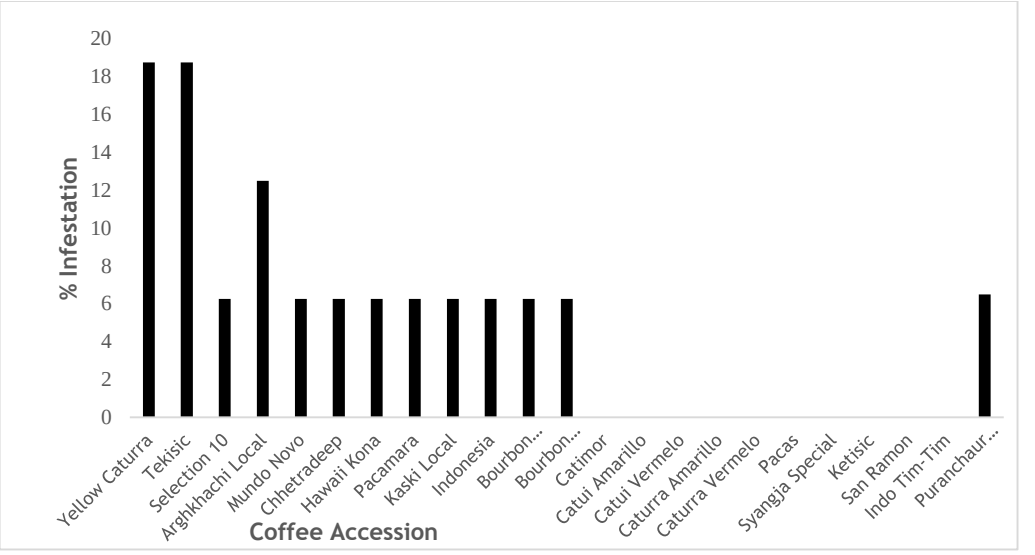

Figure 1. Percentage of coffee white stem borer infestation in different coffee genotypes

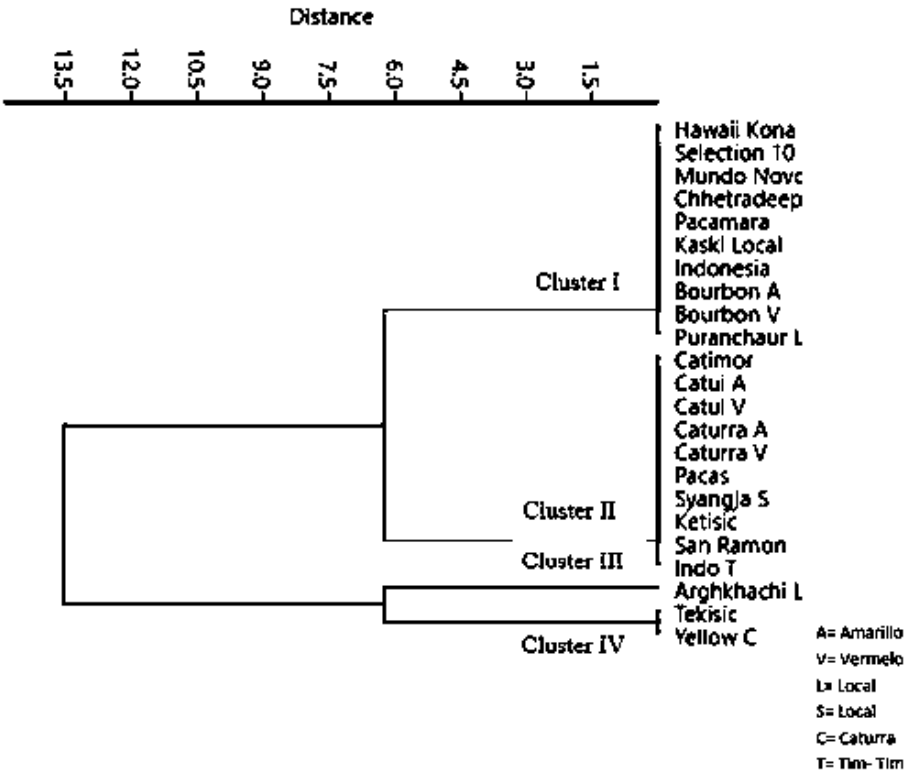

Figure 2. Similarity of coffee genotypes against coffee white stem borer infestation in Horticulture Research Station, Malepatan

Cluster analysis shows the four clusters of coffee genotypes based on the coffee white stem borer infestation (Fig. 2). The cluster II consisted of the 10 genotypes with no coffee white stem borer infestation while cluster I consisted of 10 genotypes with very few infestation (1 infested from 16 sample plants). Genotype namely Arghakhachi local located in the separate branch making cluster III which showed some level of borer infestation (2 infested from 16 sample plants) securing single lineage. Likewise, two genotypes Tekisic and Yellow caturra (3 infested from 16 sample plants) showed distinct but the highest infestation by stem borer among 23 coffee genotypes in cluster IV. The genotypes Ketisic, Yellow caturra and Arghakhachi local have thin and upright branching habit which may expose stem to insect attack but, genotypes Catimor, San Ramon and Indo Tim-Tim have horizontal and comparatively short branching habit might result to less borer attack (ARS, 2014). A similar study in India selected a new Arabica cultivar named 'Chandragiri' with good yield potential and a high tolerance to coffee white stem borer. The drooping branches of Chandragiri plants cover the entire main stem and act as a barrier against borer attack (Jayarama, 2007).Raju*et al* (2021) found that antennae of CWSB female responded significantly to 18 chemical compounds found in coffee leaves. He

concluded that the variable borer infestation to different genotypes is due to their host selection behavior based on plant volatile and the visual clues. Moreover, Morewood et al. (2004) reported the evidence of three different forms of resistance in hard wood tree species against Asian longhorned beetle- *Anoplophoraglabripennis* (Motschulsky) (Coleoptera: Cerambycidae) as antixenosis (lack of cues as a potential host), antibiosis (affect growth and reproduction) and tolerance (no damage). The same mechanism may exist in coffee against coffee white stem borer because of their similar nature of damage and same family characteristics (Coleoptera: Cerambycidae). Additionally, Magalhaes (2005) evaluated the influence of volatile compounds found in coffee leaves on oviposition preference of leaf miner, observing the positive correlation with the concentrations of p-cymene and negative with the concentrations of beta cymene. The result might be comparable with the coffee white stem borer infestation in coffee genotypes.

VARIETAL SCREENING IN COFFEE AGAINST COFFEE RUST

There was notably different level of variation in resistance to coffee leaf rust among the germplasms. The bar graph (Fig. 3) shows that three germplasms 'Catimor', San Ramon and Indo Tim-Tim reacted exceptionally high resistance against coffee leaf rust. While, Arghakhachi local and Yellow caturra found to be most susceptible coffee genotypes to leaf rust followed by Tekisic, Indonesia, Catuai and others. Similar study showed that the varieties Hibrido de Timor (HDT) and Catimor showed high levels of resistance to all Coffee leaf rust isolates, whereas Bourbon was highly susceptible genotype (Rodrigues *et al.*, 2000; Silva *et al.*, 2006).

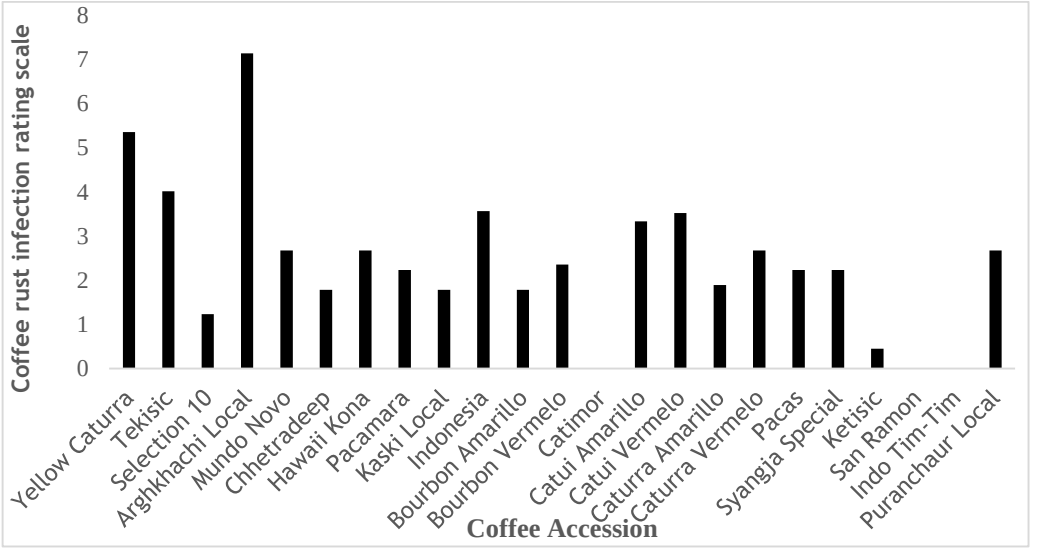

Figure 3. Response of coffee genotypes to coffee leaf rust

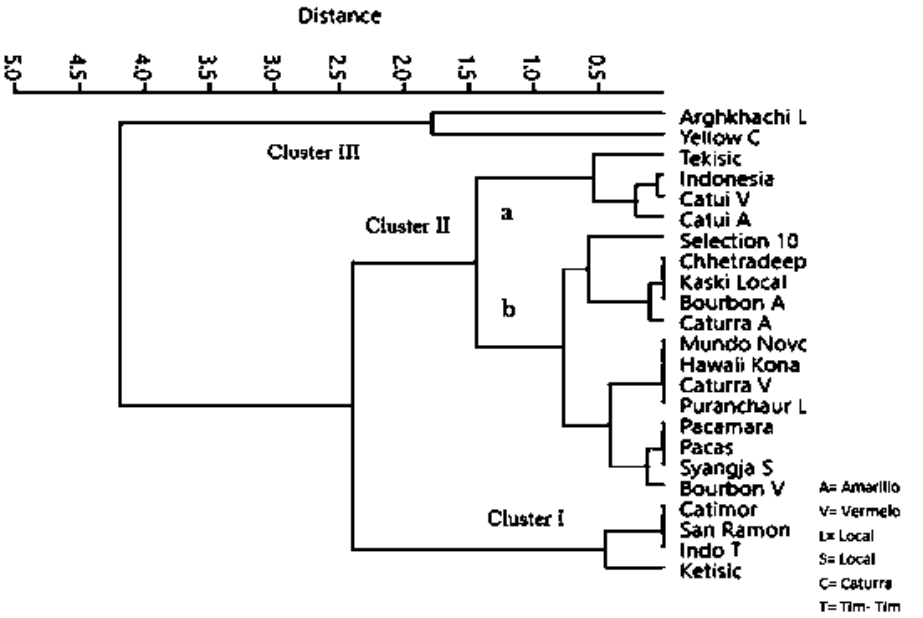

Figure 4. Variation in severity of coffee leaf rust symptoms scored by numeric scale 0 (resistant) to 9 (susceptible) at HRS, Malepatan. (The horizontal axis scale of the given dendrogram) represents the distance or dissimilarity between each cluster of coffee germplasm. The vertical axis represents the name of coffee germplasms)

The graph provides the information on similarity and differences among genotypes by clustering of coffee genotypes based on coffee leaf rust infestation. The horizontal position of the split, shown by the short vertical bar, gives the distance (dissimilarity) between the clusters of genotypes. Looking at this dendrogram, we can see the three clusters as three branches that occur at about the same horizontal distance. The cluster I consisted of the 4 genotypes including Catimor, San Ramon (dwarf variety) and Indo Tim-Tim with no leaf rust infestation and Ketisic with very low level of infestation. Similarly, cluster II comprise of further two clusters IIa and IIb, both of which again give branching to 4 and 13 genotypes, respectively with some level of infestation. Cluster III consists of 2 genotypes namely Arghakhachi local and Yellow caturra which showed distinct but highest infestation by coffee leaf rust among 23 coffee genotypes in Malepatan, Kaski condition. This indicates that most of these genotypes contained quantitative rather than qualitative kind of resistance/susceptibility. The term 'quantitative' is used when differences between genotypes are not easily distinguishable while 'qualitative' is used when different genotypes show easily distinguishable phenotypes (Eskes, 1983).This is due to most of the genotypes seems to be similar in appearance and the difference in resistance might be due to presence of resistance gene or some compounds present in the

coffee plants. The genotype Catimor is the progeny of rust resistant Timor hybrid and Caturra genotype (WCR., 2016). Dwarf accession of San Ramon is produced by incorporating rust resistant gene SH3 to original accession in India (Ram, 2006).Similar phenomenon of leaf rust in wheat (caused by *Pucciniarecondita f. sp. tritici*) is caused by the presence of Lr13 and Lr34 genes singly or together (Kolmer, 1996). The differences in resistance in all coffee genotypes might be due to occasional crossing and blending of resistant genes from genetically resistant accessions.The rust resistant gene SH3 in some accessions is suggested to have been derived from *Coffea liberica* and incorporated into *C. arabica* by the way of spontaneous hybridization and natural stabilization (Prakash *et al*, 2004).

CONCLUSIONS

The present study attempts to evaluate the response of various coffee accessions available in Horticulture Research Station, Malepatan, Pokhara, Nepal to the coffee white stem borer and coffee leaf rust under field conditions. The study successfully identified some genotypes with high resistance to stem borer and leaf rust to the area. The observation on the emergence of this borer showed that coffee genotypes "Yellow caturra" and “Tekisic” were infested heavily (18.75%) followed by Arghakhachi local (12.5%) followed by other ten genotypes. However, no stem borer infestation was observed in genotypes Catimor, San Ramon, Indo Tim-Tim, Ketisic, Pacas, Syangja special and both Vermelo and Amarillo group. Similarly, genotypes Catimor, Indo Tim-Tim and dwarf variety San Ramon were observed to be resistant against coffee leaf rust. Coffee germplasm- Ketisic was also recorded as relatively resistant against coffee leaf rust. The results obtained from this study will be useful to enhance the lineage determination and improvement of coffee varieties particularly to develop high yielding rust and borer resistant variety with further multi-location tests and molecular analysis for resistant gene or isolation of chemical compounds involved.

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USE OF BOTANICALS FOR MANAGEMENT OF WEEVIL (*Sitophilus zeamais* motschulky) IN MAIZE STORAGE

K. Basyal[1]*, R. Sapkota[1], A.S.R. Bajryacharya[2] and S. S. Bhattarai[1]

ABSTRACT

A laboratory study was conducted with the aim of evaluating efficacy of different botanical insecticides against weevil in storage with four replication in completely randomized design. Seven plant materials; Acorus calamus Linn.*, Piper nigrum* Linn.*, Zanthoxylum armatum* DC.*, Azedarachta indica* A. Juss.*, Melia azedarach* Linn.*, Justicia adhatoda* Linn.*, and Artemisia vulgaris* Linn. *were compared along with control. Maize samples were infested with S. zeamais at the rate of 4 pair adults/50 g. At 120 days of treatment, the highest and lowest number of weevil progeny (19.75 and 0.70), and grain damage% (19.50% and 0.21%) was recorded in control and A. calamus. Similarly, weight loss% was the highest on control (7.03%) and lowest on A. calamus (1.80%), followed by A. indica (2.79%) and P. nigrum (3.13%), respectively.100% weevil mortality was observed in A. calamus and P. nigrum treated grains within 14 and 21 days. A. calamus was found more effective for weevil management in storage.*

Keywords: Botanicals, maize, maize weevil, mortality

INTRODUCTION

Maize (*Zea mays* Linn.) is one of the important staple food source in Nepal after rice. The productivity of maize is 2.84 t/ha. It occupies around 27.72% area of the total cereal cultivation and 25.39% of total cereal production (SINA, 2018/19). It is the world's biggest supplier of calorie (19.5%) for body growth followed by rice (16.5%) and wheat (15%) (FAO, 2019). However, losses in maize is significantly high in storage condition (Neupane *et al*. 1991). Approximately 10-100% loss is recorded in maize due to storage pests depending upon storage structure and physical environment (Shivakoti and Manandhar, 2000). Maize weevil (*Sitophilus zeamais* Motsch.) is the most important storage pest of maize in Nepal (Manandar and Mainali, 2001). Appropriate management practices against weevils are deficient in storehouse in Nepal. Deleterious chemical compounds like aluminum phosphide, malathion, ethyl formate etc., are being practiced by farmers for its control and management (Joshi *et al*. 1991). In fact, use of celphos (aluminum phosphide) is the common practices in Nepal (Tiwari *et al*. 2018). But the haphazard use of these synthetic pesticides is being great threat to the environment and human health due to residual property (El-Salam and Ahmed, 2010). So, it is necessary to replace harmful chemical compounds with better alternatives for healthy environment and good health. Use of botanicals

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with insecticidal properties could be the best possible alternative as they are biodegradable in environment with no residue effects. Many literatures have emphasized the use of insect repellent botanical pesticides like *A. calamus* (rhizome powder), *A indica* (leaf dust, oil, seed powder), *A. vulgaris* (leaf dust), *M. azedarach* (leaf dust), *Z. armatum* (fruit powder) etc., against the storage pest (Thapa, 1996; Iieke and Oni, 2011; Iieke and Ogungbite, 2014; Bhandari *et al*. 2015; Paneru and Thapa, 2018). These plant materials have the potentiality to act as repellent against storage pest due its various chemical constituent (Neupane, 2009). Considering this fact, the research was conducted in the laboratory of National Entomology Research Centre, Khumaltar from November 2020 to May 2021 using locally available plant material with insecticidal properties against maize weevil. Hence, the main objective of this research was to find out the effective botanical against maize weevil management in storage.

METHODOLOGY

MAINTENANCE OF PURE CULTURE OF MAIZE WEEVIL

Pure culture of S. *zeamais* for the experiment was prepared at the laboratory of National Entomology Research Centre, Nepal Agriculture Research Council (NARC). The susceptible maize variety, Manakamana- 4 was oven dried at 60°C for 4 hrs to make them free from possible insect pests and excess moisture (CABI, 2007). The moisture content of maize was maintained at 14% as per method described by Cecilia *et al*. (1990). Grain moisture content was determined using WILE 65 -Moisture meter. Maize grains (200g) were kept in glass jar of 500g capacity and 50 pairs of S. *zeamais* were introduced after sexing as described by Hidayat *et al*. (1996) and left for oviposition. The set up was replicated three times in completely randomized design and samples were observed daily until emergence of F1 progenies. The mouth of the glass bottles were covered with a black muslin cloth on the top. The average temperatures and relative humidity of laboratory was recorded 26.9 ± 1.76 ºC and 35.6 ± 7.32 % by temperature hygrometer (HTC-1, Instrumentics, India) respectively. The culture so maintained was used for further research.

COLLECTION, PREPARATION AND DETAILS OF BOTANICALS

Seven botanicals with insecticidal properties such as of *A. calamus, A. indica, A. vulgaris, M. azedarach, J. adhatoda*, *Z. armatum, P. nigrum* and control was taken for the study (Table 1). The selection of these specific plant materials and their doses were based on the recommendation in literatures (Paneru *et al*. 1996; Sharma, 2014; Sharma *et al*. 2016; Tiwari *et al*. 2018; Sitaula *et al*. 2020). Leaves (with small twigs) of *A. indica, A. vulgaris, M. azedarach* and *J. adhatoda* were collected from Kawasoti, Nawalparasi. Fruit of *Z. armatum* and *P. nigrum* were procured from the market (Asan, Kathmandu). Rhizome of *A. calamus* was collected from the garden of National Entomology Research Centre, Khumaltar, Lalitpur. They were properly washed and cleaned using distilled water. Afterward, leaves of *A. indica, A. vulgaris,*

M. azedarach and *J. adhatoda* and rhizome of *A. calamus* were dried on shade for 4-5 days. Whereas, fruits of *Z. armatum,* and *P. nigrum* were dried on sun (4-5 hrs.) for 3-4 days. The dried plant materials were grinded in mixer grinder (IS 4250, Saiji, India) to bring them into powder/dust form. Then they were kept separately in airtight plastic bags in the laboratory.

The experiment was conducted in completely randomized design (CRD) with 4 replications and 8 treatments during November 2020 to May 2021.

Table 1. List of botanicals as treatments with parts used and its doses in experimental study of maize weevil management

S.N.	Treatments	Common Name	Nepali Name	Parts used	Doses	References
1	*Acorus calamus* Linn.	Sweet flag	Bojho	Rhizome powder	@10 g/kg	Tiwari *et al.* 2018
2	*Piper nigrum* Llinn.	Black pepper	Marich	Fruit powder	@10 g/kg	Sitaula *et al.* 2020
3	*Zanthoxylum armatum* DC.	Prickly ash	Timur	Fruit powder	@10 g/kg	Sharma *et al.* 2016
4	*Azedarachta indica* A. Juss.	Margosa tree	Neem	Leaf dust	@10 g/kg	Tiwari *et al.* 2018
5	*Melia azedarach* Linn.	Chinaberry tree	Bakaino	Leaf dust	@10 g/kg	Tiwari *et al.* 2018
6	*Justicia adhatoda* Linn.	Malabar nut	Ashuro	Leaf dust	@10 g/kg	Tiwari *et al.* 2018
7	*Artemisia vulgaris* Linn.	Mugwort	Titepati	Leaf dust	@10 g/kg	Sharma *et al.* 2016
8	Control	-	-	-	-	

EXPERIMENTAL PROCEDURE

Manakamana-4 variety of maize obtained from Agriculture Botany Division (ABD) was used for the study. They were sterilized (oven dried at 60^0C for 4 hrs) to eliminate insect pests and to minimize excess moisture. The grain moisture content (GMC) of oven dried maize samples were determined by using a WILE-65 Moisture meter (Farmcorp, Finland) and then adjusted to 14% GMC as per method explained by Cecilia *et al*. (1990).

Then, 50 g of maize grains were measured and separately, treated with the powder form of botanicals at the rate of 10 g/kg. They were kept in plastic bottle of 100g capacity and each bottle was infested with 4 pairs of freshly emerged sexed weevils. Holes of around 1.5—2 cm diameter was made in the lid of each bottle and then they were covered with black muslin clothes. The untreated maize grains served as a control in the experiment. Data was taken 3 times at 30 days interval. The observed parameters were parent's weevil mortality percentage, progeny emergence and grain damage percentage (weight basis). With the help of digital weighing balance, grain damage percentage was calculated whereas, parent's weevil mortality percentage and progeny emergence were found out by sieving followed by a visionary basis.

DATA ENTRY AND ANALYSIS

Data were entered using MS-excel and were analyzed using GENSTAT statistical package. Means were separated by using Duncan's Multiple Range Test (DMRT) at 5 % level of significance. The variance heterogeneity within the treatments were reduced by transforming percentage data into angular (Arc sine) value (Snodecor and Cookran, 1967) and numerical data into square root system using the formula (x+0.5) as suggested in the book of Gomez and Gomez (1984).

RESULTS AND DISCUSSIONS

PARENT'S WEEVIL MORTALITY

Among various tested botanicals, *A. calamus* was found to be most effective following *P. nigrum* in weevil mortality. The highest weevil mortality (100%) was recorded in *A. calamus* within 14 days of treatment (P<.001). 75% mortality was obtained within a week and remaining 25% was recorded in following week. In case of *P. nigrum,* 100% mortality of weevil was obtained in 21 DAT. 71.88% mortality was obtained within a week, 21.9% mortality was obtained in a second week and the remaining 6. 25% was obtained in third week. In case of control, weevil mortality was not found till the end of the experiment. After control the least mortality was recorded in *A. vulgaris* (31.26%). This result follows the findings of Sitaula *et al*. (2020), with high efficacy of *P. nigrum* and *A. calamus* in weevil mortality. Khanal *et al*. (2019) also reported 100% weevil mortality in *A. calamus* treated maize grains within 6 days of treatment. Similarly, Paneru *et al*. (1996) recorded high weevil mortality in *A. calamus* treated seeds.

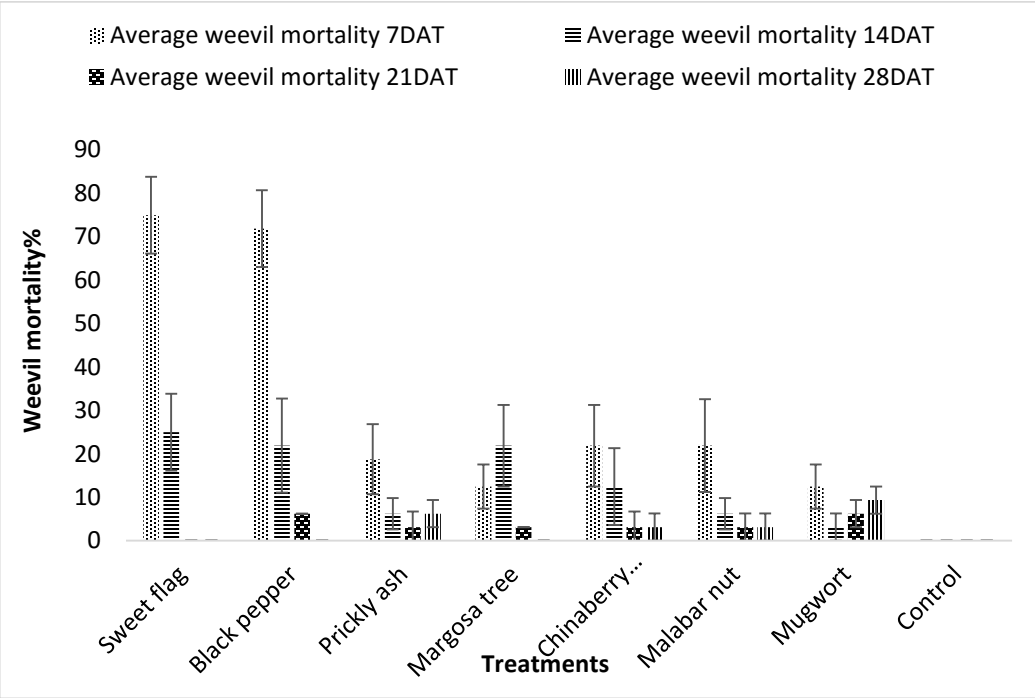

Figure 1: Effect of different treatments on weevil mortality (%) at days after treatment at storage with Standard Error of Mean (SEM). (Khumaltar, 2021)

PROGENY EMERGENCE

The progeny emergences at different date were found to be highly significant at 5% level of significance (P<.001) under various management practices (Table 2). In 60 days, highest progeny emergence was observed in control (5.00) followed by seeds treated with *A. vulgaris* (3.00) and *J. adhatada* (2.75), respectively (P<.001, F 6.09). Not a single progeny was observed in seeds treated with *A. calamus* during entire study period showing its effectiveness against maize weevil. *P. nigrum*s showed up least number of progeny emergence after *A. calamus*. All remaining treatments were found be statistically non-significant with each other. More or less similar trend was observed at 90 days of observation where the highest progeny was observed in untreated seeds (19.50) followed by seeds treated with *A. vulgaris* (13) and *J. adhatada* (11.75), respectively (P<.001, F 16.89). In 120 days, highest progeny emergence was observed in Control (19.75) followed by seeds treated with *J. adhatada* (15.00) and *A. vulgaris* (12.25), respectively. Seeds treated with *A. calamus, P. nigrum* and *A. indica* were statistically at par with lowest number of progeny emergence ((P<.001, F 18.95).

This result is supported from findings of Regmi *et al*. (2012) where fewer emergence of weevil progeny was recorded in the *A. calamus* treated seeds in the storehouse.

Similarly, Paneru *et al*. (1996) reported reduced new weevil generation in *A. calamus* treated seeds. Less weevil population was recorded in wheat seeds treated with *A. calamus* (Panthee, 1997) which follows similar result obtained in this study.

Table 2. Mean number of *S. zeamais* progeny emergence in different management practices at Khumaltar, Lalitpur, 2021

S.N.	Treatments	No. of exit holes after indicated days of treatments		
		60	90	120
1	*A. calamus* (rhizome powder)	0.00 (0.70) ^{c}	0.00 (0.70) ^{e}	0.00 (0.70) ^{c}
2	*P. nigrum*(fruit powder)	1.00 (1.22) ^{bc}	0.75 (1.05) ^{e}	0.25 (0.83) ^{c}
3	*Z. armatum* (fruit powder)	2.00 (1.53) ^{b}	5.75 (2.42) ^{cd}	7.00 (2.71) ^{b}
4	*A. indica* (leaf dust)	1.25 (1.31) ^{b}	2.25 (1.51) ^{de}	2.75 (1.60) ^{c}
5	*M. azedarach* (leaf dust)	2.25 (1.61) ^{b}	9.25 (3.10) ^{bc}	7.50 (2.83) ^{b}
6	*J. adhatada* (leaf dust)	2.75 (1.75) ^{ab}	11.75 (3.38) ^{bc}	15.00 (3.85) ^{a}
7	*A. vulgaris* (leaf dust)	3.00 (1.78) ^{ab}	13.00 (3.62) ^{ab}	12.25 (3.50) ^{ab}
8	Control	5.00 (2.32) ^{a}	19.50 (4.43) ^{a}	19.75 (4.46) ^{a}
	Grand Mean	1.53	2.53	2.57
	F-test (P value)	<.001	<.001	<.001
	LSD	0.56	0.94	0.93
	CV (%)	25.1	25.6	25

Values are means of four replications; means followed by the same letters within a column are not significantly different by DMRT at <0.05 level; CV: coefficient of variation; LSD: least significant differences. Figures in parentheses are the sq. root of (x + 0.5) transformed value of the original value.

GRAIN DAMAGE % (NUMBER BASIS)

Statistically significant differences were observed among various tested botanicals for grain damage made by weevils (Table 3). In 60 days of observation, the highest percent loss was recorded in the control seeds (4.95%) followed by seeds treated with *J. adhatada* (3.63%), *M. azedarach* (2.93%) and *A. vulgaris* (2.51%), respectively. The lowest grain damage was observed in seeds treated with *A. calamus* (0.00%) followed by *P. nigrum* (0.97%) and *A. indica* (1.81%) (P<.001, F 6.30).

More or less similar trend was observed in 90 and 120 days of observation. The highest percent loss was observed in untreated seeds (11.29%) followed by *J. adhatada* (8.41%) and *A. vulgaris* (6.85%). Seeds treated with *Z. armatum* (6.30%) and *M. azedarach* (4.47%) were statistically at par. The lowest grain damage was observed in A. calamus (0.00%) followed by seeds treated with *P. nigrum* (0.13%) and *A. indica* (1.53%) (P<.001, F 18.54). This result is supported by Regmi *et al.* (2012) where grain damage percentage was very much lower or almost negligible in *A. calamus* treated seeds in storehouse. Tiwari *et al.* (2018) also reported lowest grain damage on *A. calamus* (1.43%) and highest on control (18.02%). G.C. (2006) concluded the use of *A. calamus* (50g/kg) as effective control measure against maize weevil with minimum grain damage.

Table 3. Grain damage % (number basis) by *S. zeamais* in different management practices at Khumaltar, Lalitpur, 2021

S.N.	Treatments	Percent grain damage (no. basis) days after treatments		
		60	90	120
1	*A. calamus* (rhizome powder)	0.00 (0.21) ^{c}	0.00 (0.21) ^{e}	0.00 (0.21) ^{d}
2	*P. nigrum* (fruit powder)	0.97 (5.62) ^{b}	0.56 (3.04) ^{de}	0.13 (1.23) ^{cd}
3	*Z. armatum* (fruit powder)	2.24 (8.28) ^{ab}	4.06 (11.28) ^{c}	6.30 (14.15) ^{b}
4	*A. indica* (leaf dust)	1.81 (7.64) ^{b}	1.53 (5.78) ^{d}	1.53 (5.69) ^{c}
5	*M. azedarach* (leaf dust)	2.93 (9.62) ^{ab}	7.42 (15.48) ^{bc}	4.47 (12.04) ^{b}
6	*J. adhatada* (leaf dust)	3.63 (9.90) ^{ab}	11.07 (18.95) ^{ab}	8.41 (16.49) ^{ab}
7	*A. vulgaris* (leaf dust)	2.51 (8.50) ^{ab}	8.11 (16.33) ^{abc}	6.85 (14.90) ^{ab}
8	Control	4.95 (12.72) ^{a}	13.67 (21.63) ^{a}	11.29 (19.50) ^{a}
	Grand Mean	7.81	11.61	10.47
	F-test (P-value)	<.001	<.001	<.001
	LSD	4.28	5.31	4.94
	CV (%)	37.6	31.3	32.3
	Sem ±	1.46	1.82	1.69

Values are means of four replications; means followed by the same letters within a column are not significantly different by DMRT at <0.05 level; CV: coefficient of variation; LSD: least significant differences. Figures in parentheses are the angular transformed value of the original value.

WEIGHT LOSS %

There were variations and the significant differences were observed in botanical treated maize samples as compared to control for weight loss percent after 120 days of observation (Table 4). The lowest weight loss was recorded in *A. calamus* treated seeds (1.80%) followed by *A. indica* treated seeds (2.79%) and *P. nigrum* treated seeds (3.13%). The highest loss was found in Control (7.03%). However, seeds treated with *A. vulgaris* (6.20%) and *J. adhatada* (6.21%) were statistically at par with control (P<.001). Minimum weight loss was reported in the *A. calamus* treated seeds in the storehouse (Regmi *et al.* 2012). Tiwari *et al.* (2018) also reported lowest weight loss

in *A. calamus* (1.5%) treated maize grains and highest in control (57.3%). Likewise, maize grains treated with *A. calamus* (10g/kg) was found to be superior over maize grains treated with *Z. armatum* (3g/kg), *A. indica* (10g/kg), A. vulgaris (10g/kg) and control in case of grain weight loss as reported by Sharma *et al.* (2016).

Table 4. Weight loss (%) by *S. zeamais* in different management practices after 120 days of storage at Khumaltar, Lalitpur, 2021

Selected genotypes	Weight loss by maize weevil after 120 days
A. calamus (rhizome powder)	1.80 (7.70) ^{e}
P. nigrum (fruit powder)	3.13 (10.06) ^{bd}
Z. armatum (fruit powder)	4.36 (12.03) ^{bc}
A. indica (leaf dust)	2.79 (9.37) ^{de}
M. azedarach (leaf dust)	4.37 (12.03) ^{b}
J. adhatada (leaf dust)	6.21 (14.42) ^{a}
A. vulgaris (leaf dust)	6.20 (14.41) ^{a}
Control	7.03 (15.37) ^{a}
Grand Mean	11.93
F- test	<.001
LSD	1.94
CV (%)	11.2
Sem ±	0.66

CONCLUSIONS

All the selected botanicals were effective for management of maize weevil in storage over control. Considering weevil mortality and other economic parameters like progeny emergence, grain damage and weight loss, *A. calamus* showed effective management against maize weevil than other tested botanicals. *P. nigrum* and *A. indica,* had showed the positive results after *A. calamus* against maize weevil. This finding is important for developing an eco-friendly approach of maize weevil management in storage to escape the risk of health hazard and environment pollution from the use of deleterious chemical compounds. However, similar kinds of study need to be conducted time to time for further validation and acceptance.

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MORPHOLOGY AND CROSS INFECTIVITY OF *Sclerotium rolfsii* sacc. ISOLATED FROM DIFFERENT HOST PLANTS IN NEPAL

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ABSTRACT

Sclerotium rolfsii Sacc. is prevalent in leguminous and solanaceous crops but over the last five years, its severity has increased in several crops such as rice, onion and chilli in Nepal. A study on cross infectivity of S. rolfsii was carried out in March, 2019 at Agriculture and Forestry University, Chitwan. S. rolfsii were isolated from eight crop species viz. rice, lentil, rajma, onion, chickpea, rapeseed, soybean, and chilli. Cross infectivity of the eight isolates was done on the seven crop species in artificially inoculated soils in a screen house. Morphological characters such as mycelial growth rate, number of sclerotia formed, and size of sclerotia were studied. Morphological characters of the S. rolfsii varied among the isolates. All crop species tested were found to be susceptible to all isolates except onion isolate. Germination percentage was greatly reduced (80%) in rajma. Post emergence seedling mortality ranged between 10%in rice and chilli and 100% in chickpea, mustard lentil and rajma. The results of the present study indicate that management strategies of this pathogen should incorporate selection of non-host crops such as maize for crop rotation which helps to prevent build-up of inoculum.

Keywords: Crop rotation, germination percentage, leguminous crops, non-host crop

INTRODUCTION

Sclerotium rolfsii Sacc. is an emerging and destructive soil borne plant pathogen having a wide host range. *S. rolfsii* commonly occurs in the tropics and warm regions, causing root rot, stem rot, wilt and foot rot in crops (Farr *et al.*, 1989). Profuse mycelial growth, production of persistent sclerotia (Kokub *et al.*, 2007)are the distinguished characters of *S. rolfsii* that contribute in survival and disease development in plants. Advancing mycelia form spherical sclerotia which darken as they mature and become tan to dark brown in color. These sclerotia serve as a survival structure of the pathogen(Money, 2016).During favorable weather conditions, sclerotia germinate by producing hypha and penetrate susceptible plant parts when come into contact with plant. The fungus secrets oxalic acid and tissue degrading enzymes such as polygalacturonase and cellulase, which cause death of host cells (Mullen, 2001). Within few days after infection, symptoms of soft rot, yellowing and wilt are visible(Mullen ,2001).A wide range of symptoms such as seedling blight, seed rots, stem rot, collar rot and wilt in different host plants have been reported (Arunasri *et al.*,2011).

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Over 270 host genera have been reported to be infected by this pathogen in the U.S.A. alone (Farr & Rossman,2006). It has been reported that when legumes, cucurbits and other vegetable crops are grown in rotation with beans incidence and severity of *S. rolfsii* is high and severe(IITA,1996). Between1988 and 1994, the United States encountered a significant economic loss of $36.8 million due to *S. rolfsii* infection in peanut (Franke *et al.*, 1998).Diversity in pathogen population results in variation in virulence towards host. This often can be used for evaluation of disease resistance in crop breeding program (Paparu *et al.*, 2020). Monitoring pathogen population for virulent races is important as it provides us the knowledge of evolution in pathogen in response to crop breeding against the pathogen (Peever *et al.*, 2000).
In Nepal, *S. rolfsii* causes southern blight in vegetables, seedling blight in rice, collar rot in lentil and other diseases in different crops. In recent years, incidence and severity of the disease has been increased. *S. rolfsii* has infected rice in Sunsari, Jhapa, Morang and Udaypur districts during 2016/17(RARS,2017), onion in Dhading district during2018/19(PPD,2018), lentil, rajma, chickpea and mustard in Lumbini and Sudur Paschim province in 2015 (NGLRP,2015) till now and chilli in Chitwan. Despite the growing threat, knowledge on the morphology and pathogenicity of *S. rolfsii* from different crops and geography in the country is lacking, which are required for developing management strategies, including resistant varieties of crop plants. Thus, the objectives of this study were to determine the morphological differences in *S. rolfsii* isolated from different crops and to assess their cross infectivity.

METHODOLOGY

ISOLATION OF *S. rolfsii*

Sclerotium rolfsii was isolated from diseased root samples of six crop species collected from different locations (Table 1). Plant roots were washed and cut into small sections. The cut root samples were surface sterilized by dipping in 1 % sodium hypochlorite for 1 min, rinsed with sterile distilled water, and plated on moist chamber. The plates were incubated at 25°C in an incubator until sclerotia were produced (5-7 days) and the sclerotia produced were inoculated onto PDA and cultured. SRON isolate of onion was collected from National Plant Pathology Research Centre (NPPRC), Khumaltar, and SRRI isolate of rice was collected from RARS, Tarahara.

Table 1. List of *Sclerotium rolfsii* isolated from different crop species and locations

Crop species	*S. rolfsii* isolates	Location
Rice	SRRI	Tarahara, Sunsari
Chickpea	SRCK	Khajura, Banke
Chilli	SRCI	Bharatpur, Chitwan
Soybean	SRSY	Bharatpur, Chitwan
Onion	SRON	Naubise, Dhading

Crop species	*S. rolfsii* isolates	Location
Rapeseed	SRMD	Ghorahi, Dang
Lentil	SRLN	Ghorahi, Dang
Rajma	SRRJ	Khajura, Banke

MORPHOLOGICAL CHARACTERIZATION OF *S. rolfsii* ISOLATES

Eight *S. rolfsii* isolates were assessed for colony growth rate, color of mycelia, number of sclerotia produced, shape and size of sclerotia, and days to sclerotial initiation in completely randomized design (CRD) with three replications. Five mm diameter agar plugs from 3-day-old culture of the fungus were placed at the center of 90mmdiameter Petri dishes upside down for the better contact of the pathogen to the media and incubated at 25°C. Mycelial growth of the fungus was assessed after 24 hours of incubation by measuring colony radius .Measurements were made for 5 to 7 days, based on culture growth beyond the Petri dish base. The size of sclerotia was measured and numbers of sclerotia formed were counted at 28 days after inoculation (Mahato and Biswas, 2017).

CROSS INFECTIVITY OF *S. rolfsii* ISOLATES ON DIFFERENT HOSTS

Eight isolates of *S. Rolfsii* and seven crop species viz. rice (Hardinath-1), soybean (farmers cultivar), Rapeseed (farmers cultivar), chickpea (BG), lentil (Simrik), rajma (farmers cultivar), and chilli (Jwala) were used for the study. Mass culture of each isolate of *S. rolfsii* was prepared in the mixture of rice bran and rice husk in 1:5 proportion. Twenty-five gram of the mixture was autoclaved (121^0C at 15 PSI for 60 minutes) twice on two consecutive days and allowed to cool under sterile conditions. Then, the mixture was inoculated with 5 mm diameter sized agar plugs of 3-days-old pure culture of *S. rolfsii* and incubated for 10 days at 25^0C in an incubator.

For potting, sandy loam field soil was sterilized by using formaldehyde (4%) at the rate of 2 ml per kg soil. Sterilized soil was inoculated with them as culture of *S. rolfsii* at the rate of 2g per kg soil in pots. Sterilized soil without *S. rolfsii* was used as control. Seeds of each crop were sown in pots after 3 days of inoculation. Ten seeds were sown in a pot for small grain crops viz. rice, chilli, lentil, and mustard, whereas for large seeded crops viz, rajma, chickpea, and soybean, six seeds were sown. Completely randomized design with 3 replications was used in the experiment. The pots were placed under greenhouse conditions (29^0 C and 51 % relative humidity). Emergence of seedlings was recorded at 7 days after sowing and post emergence mortality was recorded at 10 days of planting. The reaction of the crop species to the isolates of *S. rolfsii* was categorized as follows (Prabhu and Patil, 2005):
Resistant: 0-10 percent seedling mortality
Moderately resistant: 11-30 percent seedling mortality
Moderately susceptible: 31-70 percent seedling mortality
Susceptible: 71-100 percent seedling mortality

STATISTICAL ANALYSIS

R studio was used for data analysis. To determine the effect of *S. rolfsii* isolates on seed germination percentage, and mortality percentage, values were subjected to arcsine square root transformed before analysis. Mean separation was carried out by Duncan's multiple range test.

RESULTS

MORPHOLOGICAL CHARACTERISTICS OF *S. rolfsii* ISOLATES

Morphology of eight isolates of *S. rolfsii* isolated from the different hosts were studied based on mycelial and sclerotial characters (Table 2). The highest radial growth was observed in SRLN (0.9cm) isolated from lentil in 24 hours and also covered petridish on the third day of inoculation. The mycelial growth rate on PDA medium was relatively fast for the isolates SRLN, SRRI, and SRCI isolated from lentil, rice, and chilli, respectively. While the isolates SRON and SRSY isolated from onion and soybean, respectively had slow radial growth. They completely covered the plate on the fifth day of inoculation. All isolates had bright white-colored cultural growth on PDA. The highest number of sclerotia per plate was observed in SRLN(890) and SRRI (812). While the lowest number of sclerotia per plate was observed in SRON (340), SRRJ (375), and SRMD (390). The sclerotial size was significantly larger in SRON (1.61 mm),and SRSY (1.59 mm) as compared to other isolates. Similarly, days to the formation of sclerotia varied among isolates. It took seven days to initiate sclerotia formation in SRSY while sclerotia formation was initiated within three days in SRRI.

Table 2. Mycelial and sclerotial characteristics of *S. rolfsii* isolates isolated from different crops

Sclerotium isolates	Radius (cm)				Number of sclerotia/ plate	Size of sclerotia (mm)	Days to initiation of sclerotia formation
	Day 1	Day 2	Day 3	Day 4			
SRCK	0.57^{b}	1.66^{bc}	3.04^{cd}	4.50^{a}	410^{b}	1.48^{b}	5^{b}
SRON	0.20^{d}	0.84^{d}	2.03^{f}	3.77^{c}	340^{b}	1.61^{a}	5^{b}
SRRI	0.81^{a}	2.39^{a}	3.84^{b}	4.50^{a}	812^{a}	1.14^{d}	3^{d}
SRCI	0.82^{a}	1.76^{b}	3.41^{bc}	4.50^{a}	556^{b}	1.14^{d}	4^{c}
SRSY	0.37^{c}	0.77^{d}	2.21^{ef}	3.17^{d}	546^{b}	1.59^{a}	7^{a}
SRRJ	0.48^{bc}	1.33^{c}	2.68^{de}	4.10^{b}	375^{b}	1.17^{d}	4^{c}
SRMD	0.62^{b}	1.74^{b}	3.07^{cd}	4.50^{a}	390^{b}	1.35^{c}	4^{c}
SRLN	0.94^{a}	2.16^{a}	4.50^{a}	4.50^{a}	890^{a}	1.18^{d}	5^{b}
Mean	0.56	1.58	3.09	4.19	539.87	1.33	4.62
LSD (<0.05)	0.14	0.36	0.52	0.21	250.41	0.08	0.001
F-test	***	***	***	***	**	***	***
CV(%)	14.04	12.97	9.62	2.91	26.48	3.69	0.02

S. rolfsii isolates named after host crop i.e. SRRI- rice, SRCK-chickpea, SRCI- chilli, SRSY- soybean, SRON- onion, SRMD- mustard, SRLN-lentil and SRRJ- rajma.

EFFECT OF *S. rolfsii* ISOLATES ON GERMINATION OF DIFFERENT CROPS

Soil application of *S. rolfsii* had significant effect on germination of the crop species (Table 3). Germination of the crops varied significantly with different isolate of the pathogen.

Table 3. Effect of *Sclerotium rolfsii* isolates on germination percentage of different crop species in pot culture

S. rolfsii isolates	Crop species						
	Rice	Chickpea	Chilli	Soybean	Mustard	Lentil	Rajma
SRCK	76.67 $^{a-i}$(1.08)	38.89 $^{g-k}$(0.66)	63.33 $^{a-j}$(1.01)	55.56 $^{d-k}$(0.84)	70.00 $^{a-j}$ (1.01)	93.33 ^{ab}(1.41)	26.67 ^{k}(0.38)
SRCI	46.67^{e-k} (0.75)	27.78^{h-k} (0.55)	53.33^{d-k} (0.82)	77.78^{a-g} (1.16)	76.67^{a-g}(1.15)	96.67^{ab} (1.45)	20.00 ^{k} (0.39)
SRON	100.00^{a} (1.55)	83.33^{a-g} (1.15)	90.00^{a-e} (1.30)	72.22^{a-h} (1.10)	66.67^{b-j} (0.98)	90.00^{a-e} (1.30)	53.33 $^{d-k}$ (0.82)
SRSY	86.67^{a-d} (1.33)	38.89^{g-k} (0.66)	26.67^{jk}(0.46)	38.89^{g-k} (0.67)	66.67^{b-j} (0.96)	80.00^{a-g} (1.12)	33.33^{i-k} (0.53)
SRMD	86.67^{a-d} (1.33)	55.56^{c-k} (0.85)	83.33^{a-g} (1.22)	83.33^{a-g} (1.22)	53.33^{d-k} (0.82)	90.00^{a-f} (1.25)	40.00^{g-k} (0.68)
SRLN	93.33^{ab} (1.41)	55.56^{d-k} (0.84)	80.00^{a-g} (1.12)	72.22^{a-i}(1.03)	46.67^{e-k} (0.75)	86.67^{a-f} (1.27)	20.00^{k} (0.39)
SRRJ	73.33^{a-i}(1.04)	44.44^{f-k}(0.73)	86.67^{a-d} (1.33)	72.22^{a-h} (1.10)	83.33^{a-g}(1.22)	93.33^{a-d} (1.35)	46.67^{e-k} (0.75)
SRRI	73.33^{a-i}(1.05)	44.44^{f-k} (0.73)	36.67^{h-k} (0.56)	83.33^{a-g} (1.22)	76.67^{a-i}(1.08)	90.00^{a-e} (1.30)	20.00^{k} (0.39)
Control	100.00 ^{a}(1.55)	94.44^{ab}(1.42)	96.67^{ab}(1.4 5)	94.44 ^{ab}(1.42)	93.33^{ab}(1.4 1)	100.00^{a}(1. 55)	93.33 $^{a-c}$(1.40)
Mean	1.029163						
LSD ($p<0.05$)	0.4378						
F test	*						
CV (%)	26.32						

Figures followed by the same letter in column are not significantly different by DMRT. Figures in the parentheses are arc sin transformation values. S. rolfsii isolates named after host crop i.e. SRRI- rice, SRCK-chickpea, SRCI- chilli, SRSY- soybean, SRON-onion, SRMD-rapeseed, SRLN-lentil and SRRJ- rajma.

Germination of Chickpea and rajma were greatly reduced (up to 27.78% and 20%, respectively) compared with the crop species(Table 3). Germination of rapeseed, chilli and lenti lseeds were reduced ($p< 0.05$). Germination of rice was not significantly for the isolates of *S. rolfsii*, except for SRCI (46.67%).

MORTALITY OF CROP SPECIES DUE TO *S. rolfsii*

All the isolates of *S. rolfsii* were cross infective on the tested crop species (Table 4). There were differences in seedling mortality among the crop species ranging from 0% to 100% (Table 4).

Table 4. Cross infectivity of different isolates of S. rolfsii on different crop species

S. rolfsii Isolates	Crop species						
	Rice	Chickpea	Chilli	Soybean	Mustard	Lentil	Rajma
SRCK	26.46 $^{i-o}$ (0.46)	100.00 $^{a-c}$ (1.53)	10.00 $^{m-o}$ (0.21)	70.00 $^{a-i}$ (1.06)	90.74 $^{a-f}$ (1.31)	63.33 $^{a-l}$ (0.92)	83.33 $^{a-f}$ (1.28)
SRCI	63.33^{a-j} (1.00)	50.00^{d-n} (0.79)	95.24^{a-e} (1.43)	45.56^{e-n} (0.74)	74.17^{a-j} (1.04)	57.78^{c-m} (0.87)	100.00^{a-c} (1.53)
SRRJ	68.25^{a-k} (0.97)	88.89^{a-f} (1.34)	44.44^{f-n} (0.72)	47.22^{e-n} (0.75)	70.24^{a-j} (1.01)	71.48^{a-j} (1.01)	88.89^{a-f} (1.34)
SRSY	20.00^{j-o} (0.37)	100.00^{a-c} (1.54)	75.00^{a-g} (1.20)	100.00^{a-c} (1.54)	100.00^{ab} (1.55)	62.96^{a-l} (0.92)	50.00^{a-f} (1.28)
SRMD	14.44^{k-o} (0.32)	56.67^{a-l} (0.93)	12.86^{k-o} (0.30)	31.67^{g-o} (0.59)	100.00^{a-c} (1.55)	100.00^{a} (1.55)	61.11^{a-k} (0.97)
SRLN	10.00^{l-o} (0.27)	46.67^{e-n} (0.76)	27.31^{h-o} (0.47)	44.44^{f-n} (0.73)	100.00^{a-c} (1.55)	92.96^{a-f} (1.34)	100.00^{a-c} (1.53)
SRON	10.00^{m-o} (0.20)	60.00^{a-l} (0.89)	35.56^{g-o} (0.55)	25.00^{g-o} (0.52)	64.35^{a-j} (1.01)	55.65^{d-m} (0.84)	50.00^{d-n} (0.79)
SRRI	96.30^{a-d} (1.44)	55.56^{d-m} (0.84)	51.19^{b-m} (0.87)	46.67^{e-n} (0.75)	76.39^{a-h} (1.14)	77.22^{a-i} (1.08)	83.33^{a-f} (1.28)
Control	13.33 $^{j-o}$ (0.37)	5.56 ^{no} (0.15)	0.02 ^{o} (0.00)	0.00 ^{o} (0.02)	11.67 $^{l-o}$ (0.29)	3.33 ^{no} (0.12)	0.00 ^{o} (0.02)
Mean	0.8852						
LSD (p<0.05)	0.539						
F test	***						
CV (%)	27.07						

Figures followed by the same letter in column are not significantly different by DMRT. Figures in the parentheses are arc sin transformation values. S. rolfsii isolates named after host crop i.e. SRRI- rice, SRCK-chickpea, SRCI- chilli, SRSY- soybean, SRON-onion, SRMD-rapeseed, SRLN-lentil and SRRJ- rajma.

Seedling mortality was significantly higher in lentil due to SRMD (100%) (P <0.0001). Rice was susceptible to *S. rolfsii* isolate SRRI (96.30 %), and moderately susceptible to SRCI (63.33 %) and SRRJ (68.25 %)while resistant to other isolates. 100 % seedling mortality was observed in chickpea due to SRCK and SRSY. Chickpea was moderately susceptible to other isolates. Similarly, soybean was susceptible to SRSY with100 % seedling mortality. Isolate SRCI caused 95.24 % seedling mortality in chilli. Chilli was resistant to SRCK (10 %) and moderately resistant to other isolates. Mustard and

rajma were susceptible to all isolates of *S. rolfsii* and has high seedling mortality than other crops. Similarly, lentil was susceptible to SRMD (100%), SRLN (92.96 %)and SRRI (77.22 %), while moderately susceptible to other isolates of *S. rolfsii*. All isolates of the pathogen were virulent towards the crop species with an average mortality greater than 50 %. However, average seedling mortality due to SRON was only 42 %. While SRSY caused highest average seedling mortality (72.56 %).

Seedling mortality was found positively correlated with numbers of sclerotia with significant correlation coefficient, r = 0.369 ($p<0.05$) (Figure 1).

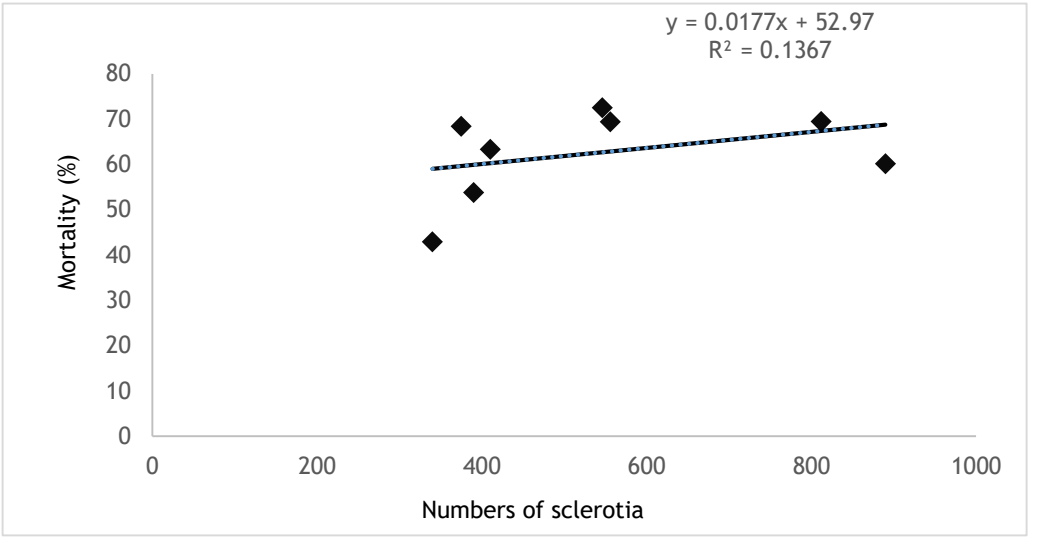

Figure 1. Relationship between seedling mortality and numbers of sclerotia produced

DISCUSSIONS

S. rolfsii is difficult to control due to its wide host range and persistent sclerotia in the soil. Knowledge on the diversity of the pathogen help develop management strategies. The diversity of *S. rolfsii* has been studied by different researchers in different countries such as in peanut in the USA and Japan (Franke *et al.*, 1998;Okabe & Matsumoto, 2000), in cantaloupe, tomato, eggplant, peanut, pepper, snap bean, sweet potato, water- melon, and several ornamental species in USA (Xie *et al.*,2014), in sweet potato in Korea(Paul *et al.*, 2017),in rice and tomato in India (Biswas & Mahato,2017).

In the present study we examined the variations in mycelial growth rates, number and size of sclerotia produced, number of days required to sclerotia formation by the isolates of*S. rolfsii* isolated from eight crop species. Similar results was reported by Le *et al.* (2012) they observed 79 to 1,080 number of sclerotia per plate and their size ranging from 0.88 to 2.24 mm. Similarly, Paul *et al.* (2017) observed 2 to 248

sclerotia per plate size ranging from 0.5 to 2 µm. It was observed that those isolates which require a longer duration to form sclerotia had a slow mycelial growth rate and had larger sclerotial size than the fast growing isolates. Kokub *et al*. (2007) and Manu *et al*. (2018) reported similar results. They found some isolates were comparatively fast growing and produced the higher number of sclerotia than the others. In the present study, the size of the sclerotia varied with isolates. The average size of sclerotia was 1.33 mm. Similar size of sclerotia had been reported for *S. rolfsii* in different crops in Korea(Paul *et al.*,2017).

In this study, we observed a significant reduction in germination percentage of crops due to infection by *S. rolfsii* isolates. Germination was reduced upto 80 % in rajma, 66% in chick pea, and about 40 % in chilli, while rice, lentil, and rapeseed were least affected. This difference in germination among crops by *S. rolfsii* may be due to the reduction of germination speed of different crops. Lentil, rice and mustard have smaller seed size and germinate rapidly as compared to larger seeded crops. Research carried out on different crops such as bean (Al- Rifaee *et al*., 2004; Alngiemshy *et al*., 2020), iron tree(Dera *et al*., 2019), canola (Hwang *et al*.,2014), chilli (Sanjuan-Martínez *et al*.,2020)showed that smaller seeds germinated faster than larger seeds. Although chilli has a small seed size it took longer time to germinate and hence has low germination percentage. According to Kirkpatrick & Bazzaz (1979) rapid emergence of seeds reflect a short period of susceptibility to infection while late emerging seeds would have longer period of susceptibility. This could increase a period of exposure to infection resulting in higher frequency of infection and increased mortality of seeds.

In our study, the infectivity of eight isolates varied among the seven tested crops, ranging from 10 to 100%.The post-emergence mortality caused by all isolates was high in mustard and rajma compared to the other crops. Similar pathogenic variability among *S.rolfsii* isolates on different crops was demonstrated by several earlier workers, on pepper and tomato (Xie *et al*., 2014),on tomato (Biswas & Mahato, 2017), on common bean (Paparu *et al*., 2020).Seedlings are very susceptible to *S. rolfsii* and die quickly once they become infected(Gawande *et al*.,2020). In this study, we found that all the isolates caused infection to all studied crops but, with varied levels of infection and were mostly virulent on their crop species of origin. Similarly, isolates from leguminous crops were more virulent towards the legume crops. However, the isolate from ricewas virulent to all crop species, except soybean.

In the present study, we observed a positive correlation between the number of sclerotia formed and seedling mortality. Similar results were reported by Paparu *et al*. (2020) in their study where they observed that those isolates which produced high numbers of sclerotia on PDA media exhibited a high degree of aggressiveness.

CONCLUSIONS

S. rolfsii is now becoming a major threat to different crops in Nepal. It is essential to understand the variability in the isolates of *S. rolfsii* causing different diseases in various host crops. The isolates from different crop species showed diversity in their morphology and virulence. This pathogen is difficult to control as the host crop species are large in number. For successful management of this pathogen, the sources of disease inoculums should be reduced which can be achieved by removing the affected plant parts and adopting the crop rotation with non- host crops wisely.

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IMPACT OF COOPERATIVE MEMBERSHIP ON ADOPTION OF IMPROVED GOAT PRODUCTION PRACTICES IN CHITWAN DISTRICT OF NEPAL

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ABSTRACT

Lack of proper production practice is identified as constraint in production performance of goats. In this context, this study attempts to assess the impact of cooperative membership on adoption of improved production practices among smallholder goat farmers. The analysis is based on data obtained from in-person interview among 327 cooperative members and 334 non-members. The study employs Poisson regression model with endogenous treatment to address the endogeneity. The findings show that cooperatives strongly facilitate adopting improved production practices among goat farmers. Average treatment effect is 2.607, and the average treatment effect on treated is 2.11 and 1.447 in nearest neighbor matching and inverse probability weighted regression adjustment, respectively. The number of improved practices shows non-linear relation with livestock unit. The number of improved production practices increases with training and decreases with distance from tar road. The finding suggest scope to increase the adoption of improved production practices through cooperative membership.

Key words : Cooperative, endogeneity, goat, imporved production practices, smallholder farmers

INTRODUCTION

In most developing nations, smallholder farming plays an essential role in animal production. Smallholder agriculture relies heavily on livestock, and goats are raised by the majority of farmers in developing nations. Smallholder farmers in tropical Asian countries raise livestock in traditional and ancestral ways, with few inputs and limited technical improvement, resulting in low output. Smallholder goat farmers in Nepal show a lack of commitment to better management practices, resulting in low goat productivity (Redding *et al.*, 2012). As a result, smallholder farmers are unable to perform to their full potential because production efficiency is heavily dependant on the farmers' goat-raising practices. Improving smallholder farmer performance is seen as a critical strategy for rural development and poverty reduction in agro-based developing countries (Mendola, 2007). As a result, it's critical to encourage and support smallholder farmers to adopt better goat-raising practices.

As a result, smallholder farmers are unable to perform to their full potential because

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production efficiency is highly dependent on the farmers' goat-raising practises. Improving smallholder farmer performance is seen as a critical component of rural development and poverty reduction in agro-based developing countries (Mendola, 2007). As a result, it's crucial to encourage and support smallholder farmers to adopt better goat-raising practises.

In Nepal, the number of cooperatives is steadily expanding year after year. The number of cooperatives had grown to 34,837 by the end of the fiscal year 2019/20, with 65, 15,460 members. Heifer International, Nepal presented strong evidence that a farmers' cooperative may be the ideal option to function as an aggregating agency and improve goat farmers' efficiency under the Smallholders' Livestock Value Chain Project launched by the organisation in 2012. (Heifer International, 2012). A total of 113 cooperatives have been working to assist goat farmers in 30 districts across Nepal with this goal. However, no systematic research has been conducted to determine the effectiveness of cooperatives in supporting farmers. As a result, the purpose of this study is to look into the impact of cooperative membership on farmer motivation.

CONCEPTUAL FRAMEWORK

Figure 1 depicts a straightforward path. Agricultural cooperatives promote technology among smallholder farmers through training and awareness (Ma, Abdulai, and Goetz, 2018; Wollni and Zeller, 2007). Farmers get assistance from government and non-government linkage and affiliation (Johnson and Shaw, 2014). Thus, cooperatives, directly and indirectly, facilitate improved practices that help to acquire better productivity and higher income (Hoken and Su, 2018; Kumar *et al*., 2018; Michalek *et al*., 2018). Higher income motivate farmers for improved practice. This pathway has been realized by various studies which reveal the positive role of agricultural cooperatives to enhance technology adoption and improvement in farm output and revenue (Hoken and Su, 2018).

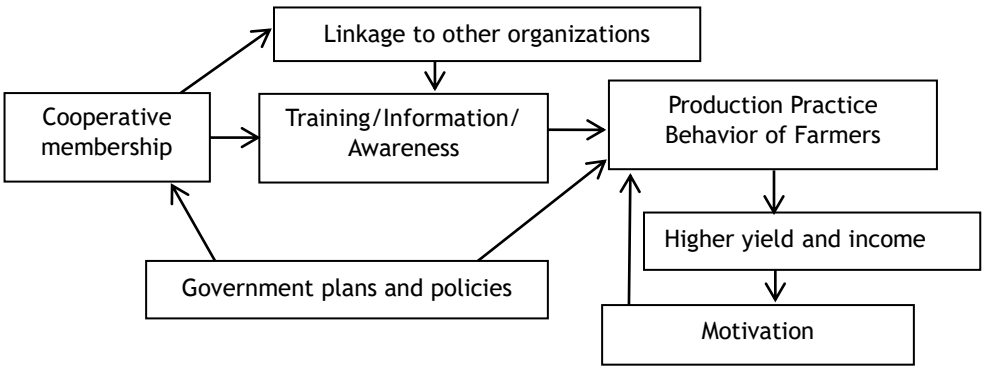

Figure 1. Conceptual framework

STUDY AREA, SAMPLING AND DATA

Smallholder goat farmers are included in the sampling frame. A multi-stage stratified random sampling procedure is used to choose the samples. Two districts, Chitwan and Nawalparasi, have been designated as the primary goat-producing areas (Kolachhapati and Devkota, 2012). Two villages from Chitwan district (Siddhi and Shaktikhor with altitudes of 750 masl and 550 masl, respectively) were chosen to represent Nepal's hilly regions, while two villages from Nawalparasi (Deurali and Nayabelhani with altitudes of 170 masl and 240 masl, respectively) were chosen to represent the plain region (Figure 2). The sampling frame is collected from HEIFER International, Nepal, an international non-governmental organisation that supports regional cooperatives, in the form of a list. The non-members were chosen at random from a list of village households. The cross-sectional household-level data are obtained through in-person interview.

The dependent variable is the score for improved production practices adopted by farmers. Table 1 describes the list of improved production practices to count the score of improved practices as a dependent variable in the analysis.

Table 1. Description of production practices

Practices	Description
Selection of breeding stock	Selection of strong and healthy male and female for breeding (culling of weak stock).
Proper age of castration	Age of 8 to 12 weeks is considered ideal when burdizzo castrator is used
Fodder sufficiency	Sufficient amount of green fodder either from own source or forest
Provision of iodine added salt	Provide goat with regular salt supplemented with iodine
Mineral block	Mineral blocks prepared by farmers and hanged near drinking water/shed
Sufficient spacing	Goats have sufficient as per their age and condition
Ventilation	Proper ventilation provided in the shed
Raised housing	Shed of goats should be raised at about 1 meter from ground level
Vaccination	Regular vaccination for contagious disease
Wormicide	Provide regular wormicide to every goat

EMPIRICAL MODEL

The study uses a Poisson regression model aided with an endogenous binary-treatment variable. Endogeneity is a common realistic situation that causes empirical challenges; therefore, failure to control them may lead to biased and inconsistent estimators (Heckman, 1979). Possibility of endogeneity of membership in an agricultural cooperative cannot be denied because membership decision is self-selected. The study aims to explore the intensity of improved practices adopted by smallholder goat farmers and address endogeneity.

The dependent variable is a count variable with a non-negative integer value from 0 to 10, where 0 indicates no improved practices adopted and 10 indicates the maximum number of approaches adopted. The analysis intends for estimation of binary choice (member or non-member) model with endogenous behavior. Therefore Poisson regression model aided with an endogenous binary-treatment variable is used to assess the factors affecting the number of improved practices adopted by the members and non-members of a cooperative. The membership in cooperative being a binary dummy variable.

The equation for outcome and treatment is expressed as:

$$E(\mathrm{y}_i / \mathrm{x}_i, \mathrm{m}_i\, e_i) = \exp(\beta x_i + \delta t_i + e_i) \quad (1)$$

$$\mathrm{m}_i = 1, if\ \mathrm{t}_i \Upsilon + u_i > 0 \text{ and } \mathrm{m}_i = 0, \text{ otherwise}$$

i.e. $\mathrm{t}_i \Upsilon + u_i$ is the likelihood of household membership in the cooperative.

Where, Y_i is an outcome, X_i are the independent variables of the model, t_i are covariates for treatment model, e_i and u_i are error terms with bivariate normal distribution with the mean value 0. The covariance matrix is:

$$\begin{bmatrix} \sigma^2 & \sigma\rho \\ \sigma\rho & 1 \end{bmatrix}$$

The covariates X_i and t_i are exogenous, i.e., unrelated to the error terms.

The dependent variable in the model is the number of improved production practises used by goat farmers. Explanatory variables include socioeconomic and farm factors, as well as cooperative membership (m), which indicates whether a household is a member ($\mathrm{m}=1$) or non-member ($\mathrm{m}=0$).As a result, the dummy endogenous-variable model allows for the joint determination of outcomes and treatment status, allowing for joint treatment and effect estimation. However, because membership is self-selective, there is a chance that cooperative membership is endogenous. A household's decision to join a cooperative, for example, can be influenced by the motivating component like visit to an NGO/ INGO's.

RESULTS AND DISCUSSIONS

DESCRIPTION OF DEPENDENT VARIABLE

Table 2 shows the frequency distribution of different improved practices among members and non-members. Findings show that less than one-fourth of the farmers are maintaining strong females for breeding. The findings are similar to a previous study that reports that only 27% of farmers adopt proper breeding practices in a village of Syangja district of Nepal (Nepali *et al.*, 2007). Other findings also report that farmers do not cull their goats to maintain strong breeding stock (Mhlanga *et al.*, 2018; Dossa *et*

al., 2015). The majority (82%) of cooperative members and only 7.5% of non -members castrated their goats at the appropriate age.

The majority of members (96.6%), as well as a non-member (89.6%), have sufficient fodder for their goat. The Source of fodder in the study site included annual or perennial grasses or fodder trees in the farmers' field or from the forest nearby. Feeding concentrate is also important for better performance of goats and goats should be feed according to their stage. In the study site, concentrates are homemade in all households. Redding *et al*. (2012) also reported a similar condition where none of the goat farmers is using commercial feed for goat. The average quantity of concentrate fed by the member is 229.36 grams while for non-member is 142.39 grams. Supplement feed also plays a remarkable role in the growth and development of animals. Iodine supplemented salt was regularly provided by 96.6% of members and 89.6% of non-members. Only less than one-third of members and less than one-fourth of non-members were preparing the mineral block for their goats.

The study shows that only about 12% of non-members have raised shed for their goats while all the members have raised shed.The majority (89%) of members and less than one-third (31%) of non-members are vaccinating their goats against PPR. Similarly most of the members (98.8%) used regular wormicides, while less than one-fourth (20.9%) of non-members were protecting their goats using regular wormicides.

Table 2. Frequency of adoption and non-adoption of practices

Practices	Member (%)		Nonmember (%)		Total (%)		x^2 test (p-value)
	Yes	No	Yes	No	Yes	No	
Selection of breeding stock	76 (23.2)	251 (76.8)	74 (22.1)	260 (77.9)	150 (22.7)	511 (77.3)	0.781
Castrate at an appropriate age	268 (82.0)	59 (18.0)	25 (7.5)	309 (92.5)	293 (44.3)	368 (55.7)	0.000
Sufficient fodder	311 (95.1)	16 (4.9)	260 (77.9)	74 (22.1)	571 (86.4)	90 (13.6)	0.000
Regular iodine added to salt	316 (96.6)	11 (3.4)	300 (89.6)	35 (10.4)	616 (93.1)	46 (6.9)	0.000
Mineral block	98 (30.0)	229 (70.0)	74 (22.1)	260 (77.9)	172 (26.0)	489 (74.0)	0.021
Sufficient space	321 (98.2)	6 (1.8)	279 (83.6)	55 (16.4)	600 (90.8)	61 (9.2)	0.000
Sufficient ventilation in shed	311 (95.1)	16 (4.9)	270 (80.9)	64 (19.1)	581 (87.9)	80 (12.1)	0.000
Raised shed	327 (100)	0 (0.0)	39 (11.6)	295 (88.4)	366 (55.3)	295 (44.7)	0.000
Regular	291 (89.0)	36 (11.0)	104	230 (69.0)	395 (59.7)	266	0.000

Vaccination			(31.0)			(40.3)	
Wormicide	323 (98.8)	4 (1.2)	70 (20.9)	70 (79.1)	393 (59.4)	268 (40.6)	0.000

DESCRITION OF EXPLANATORY VARIABLE

The explanatory variables include socioeconomic characteristics, farm characteristics, and institutional supports received by the farmers. The data of household characteristics include characteristics of the household head because the household head is mostly responsible for decision making of the economic activities in the family. The age, gender, and schooling years of the household head is therefore considered in the study. The family characteristics included in the study are the number of members involved in agriculture, the help of male members in household works, migration of family members for employment purposes, and ethnic group of the family. The characteristics of the family are an essential consideration for goat farming because family members mostly carry out smallholder agriculture as a family profession. The migration status is proxy for additional income through remittance. Migration reduces the workforce and thus affect agriculture activities, and at the same it is a source of off farm income which may reduce the agricultural activities (ILO, 2019). The farm characteristics are denoted by the variables like landholding status, distance from road head/tar road and number of goats in the farm. The institutional service is represented through training in goat management and other supports. The institutional support are source of information and motivation which may determine the goat rearing practices.

Table 3 describes the explanatory variables used in the empirical analysis. The number of members involved in agriculture is higher in member households than non-members, and the help of male members is higher in member households. The proportion of non-elite groups is higher among members while non-members consist mainly of the elite group. Member households have a higher probability of receiving training on goat management. Other variables are not significantly different among members and non –members.

Table 3. Definition and summary statistics of the selected variable

	Description	Members	Non-members	Difference	Mean
District	0= Nawalparasi, 1= Chitwan	0.658	0.642	0.016	0.650
Age of household head	Continuous	51.492	50.510	0.982	50.995
Gender of household head	0= Female, 1= Male	0.887	0.845	0.042	0.866
Schooling years of household head	Continuous	4.602	3.994	0.608	4.295
Members in agriculture	Continuous	3.511	2.875	-0.636***	3.189
Male members help in household works	0= No, 1= Yes	0.817	0.696	-0.121***	0.755

Migration	0= No, 1= Yes	0.220	0.364	-0.144	0.293
Elite group	0= No, 1= Yes	0.110	0.319	0.209***	0.216
Landholding (hectare)	Continuous	0.399	0.353	0.047	0.376
Landholding^2 (hectare^2)	Continuous	0.164	0.127	0.036	0.145
Distance from tar road	Continuous	3.737	3.893	-0.156	3.816
Livestock unit (LSU)	Continuous	4.259	1.686	2.574***	0.341
Livestock unit ^{2} (LSU^2)	Continuous	20.215	3.879	16.336***	2.957
Training on goat management	0= No, 1= Yes	0.535	0.152	0.383***	0.341
Visit to NGO/INGO	0= No, 1= Yes	0.223	0.060	0.164	0.140

Note: *** indicates significant at 1% level,.

Table 4 represents the two-stage selection model where cooperative membership is estimated in the first step and improved practices for goats in the second step. It evaluates the factors influencing a farmer's decision to become a cooperative member (column 2nd) and factors that affect the adoption of improved practices (column 3rd). The analysis estimates both outcome equations jointly.

DETERMINANTS OF COOPERATIVE MEMBERSHIP

The study assumes that farmers join cooperatives if they feel it beneficial. Cooperative membership exerts cost in terms of money, time, dedication and bound for various activity, therefore, farmers join cooperative only if they have a higher opportunity cost. Column 2 of Table 4 shows that age and gender of the household head do not make a difference in membership decisions. The results are consistent with Ankrah *et al*. (2021). However some studies shows that female headed household (Ma *et al*., 2018, Verhofstadt and Maeertens, 2015) and older farmers are more likely to be cooperative member (Chagwiza, Muraduab and Ruben, 2016; Wossen *et al*., 2017). The schooling years of the household head has positive and significant impact on the cooperative membership. Previous findings also show positive impact of education on membership decisions (Ankrah *et al*., 2021; Verhofstadt and Maertens, 2015). Households with a higher number of members in agriculture are more likely to be involved in cooperative indicating that dependency of households on agriculture motivates membership as reported by Ma and Abdulai (2016). Members from the elite group are less likely to be cooperative members as compared to non-elite. This might be because of off-farm income sources bieng more educated people. Here elite and non-elite groups are classified based on the caste system, which prevails in most South Asian countries. Landholding size and distance of household from tar road have a non-significant impact on membership. The land holding of household is a proxy for wealth. Studies show that probability of cooperative memrbship increases with land holding (Verhofstadt and Maertens, 2015; Wossen *et al*., 2017) and other shows negative relation between land holding and cooperative membership (Chagwiza, Muraduab and Ruben, 2016). The livestock unit (LSU) positively impacts membership. Farmers visiting the office of NGOs/INGO are more likely to be involved in cooperative

as these organizations advocates for cooperative membership.

DETERMINANTS OF SCORE

Column 3 of Table 4 deduces the factors affecting the adoption of improved practices (score). The non-significant effect of landholding size in adopting improved production practices indicates that smallholder farmers can efficiently manage goats in the mixed farming system. The non-significant impact of the district on the score of adoption of improved practices indicates that farmers in both plains and hills can properly manage goats. Farmers' characteristics: age, gender, and schooling years of the household head do not affect adoption of improved production practices. This is primarily because goats being easy to handle due to smaller size and gentle nature can be well managed by all ages of males and females. Also, even the less educated household heads are adopting improved production practices which might be because goat farming has been carried out by farmers as family business since long. The findings are in line with the findings in Ghana where the score of technique adoption was equal among men and women (Doss and Morris, 2000). Further, the cooperation of male members in household works resulted in more improved practices. The non-significant effect of landholding size indicates that agricultural activities do not affect goat production practices among smallholder farmers. The significant negative impact of distance of household from tar road on adoption of improved practices may be because of higher transaction cost for .distant households.

Migration of youth male for employment does not affect adoption of improved production practices for goats. This shows that goat farming can be effectively carried out by the women as reported by Neupane *et al*. (2018). The non-linear relation between number of goats in terms of livestock unit and adoption of improved production practices indicated that the number of improved production practices decreases after a threshold of a number of goats in the farm. The result shows that number of improved production practices adopted by the farmer increases till the livestock unit of goats is seven which is equal to about 25 matured goats. The analysis uses a livestock unit for the number of goats as a representation of various goats, and the livestock unit gives a systematic measure for goats of varying ages. Live weight of animal of 400-500 kg is measured as 1 LU. Thus on an average a smallholder farmers can provide proper management practices to about 25 matured goats. The positive impact of training indicates that goat farmers is supported by findings of Mhlanga *et al*. (2018).

This paper focuses to access the impact of cooperative membership on adoption of improved production practices. The result of this study is in line with the result from turkey which shows a positive impact of cooperative membership on goat production efficiency (Cinemre *et al*., 2006). This result is also verified through the density distribution of score of improved production practices (Figure 3). Consistent result is

observed in average treatment effect for both matched and unmatched sample from different matching methods: nearest neighbor matching and inverse probability weighted regression adjustment.

Table 4. Poisson regression with endogenous treatment

Score	Coefficient (Robust Std. Err.) First stage probit estimates	Coefficient (Robust Std. Err.) Second stage estimates
District		-0.031 (0.035)
Age	-0.002 (0.006)	-0.001 (0.001)
Gender	0.320 (0.209)	0.0356 (0.032)
Schooling years	0.042 ** (0.021)	0.001 (0.000)
Members in agriculture	0.169* (0.105)	0.054** (0.021)
Male members help in domestic works	0.443** (0.191)	0.068* (0.039)
Migration for employment		0.010 (0.006)
Elite group	-0.640** (0.216)	
Area (hectare)	0.343 (1.419)	3.229 (2.020)
Area^2 (hectare^2)		-3.021 (2.547)
Distance from tar road	0.023 (0.026)	-0.055* (0.015)
Livestock unit (LSU)	0.879*** (0.073)	0.084** (0.038)
Livestock unit ^{2} (LSU^2)		-0.008** (0.004)
Training in goat	0.126* (0.165)	0.165 *** (0.036)
Help of NGO/INGO	0.712*** (0.206)	
Cooperative (outcome mean)		0.362 *** (0.062)
Constant	-3.98 ** (0.709)	0.420 (0.400)
/athrho	-1.769 ** (1.067)	
/lnsigma	-4.393 ** (1.659)	
Rho	-.9435576 (0.117)	
Sigma	0.012 (0.021)	

Note: ***, ** and * indicates significant at 1%, 5%, and 10% level, respectively. Statistical computations are based on the authors' questionnaire

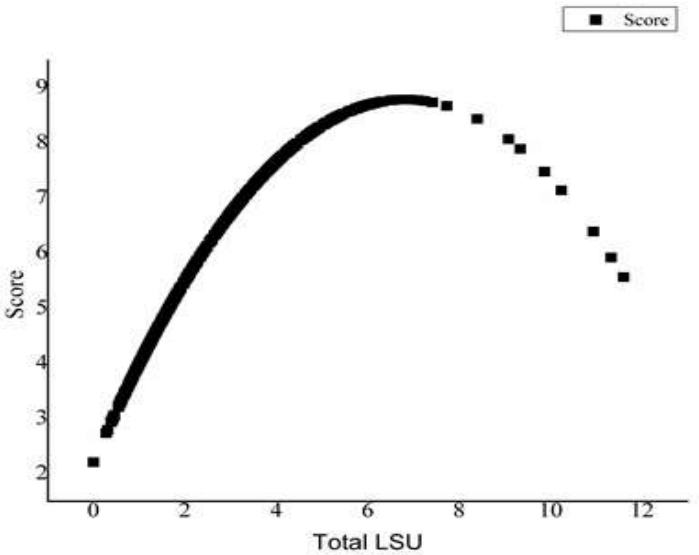

Figure 2. Score in relation to total LSU

Cooperative (outcome mean) coefficient specifies the logarithm value of the ratio of the treated potential outcome means to control potential outcome mean. A positive value of Cooperative (outcome mean) signifies a higher potential mean of treatment. The significant value of the Wald test for independent equations suggests the endogeneity of cooperative membership, and neglecting this aspect would give biased result. A similar effect of regressors in both regimes explains that the treatment variable does not interact with the outcome variable and therefore cancel from the ratio of potential-outcome means.

Figure 3 shows the right shift of distribution with a higher peak for members compared to nonmembers indicatting that cooperative membership positively impacts the adoption of improved production among goat farmers.

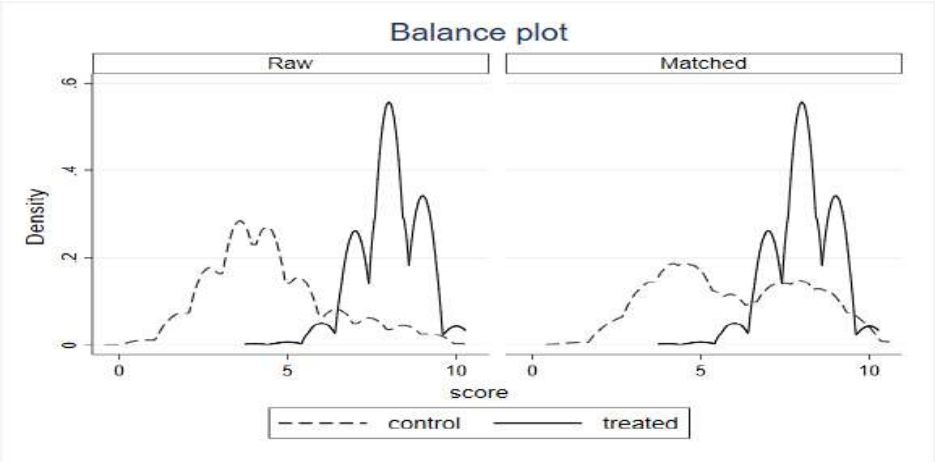

Figure 3. Density distributions of score among members and non-members

The result is consistent for both unmatched and matched samples. The matching is performed through the five nearest neighbor mating method of the propensity score. The result of cooperative membership's impact assessment is presented in Table 5. The average treatment effect on treated shows the difference between improved practices in cooperative members after being involved in cooperative and before being a member. The result shows that cooperative memberships have a significant and positive impact on adopting improved practices for rearing goats.

Table 5. Impact of cooperative membbership on adoption of imporved production practices

	outcome indicator	Members	Nonmembers	Treatment effect	%Change
Average treatment effect	Score	8.111 (.0856)	5.504 (.134)	2.607*** (0.155)	47.37

Note: *** indicates significant at 1%.Statistical computations are based on the authors' questionnaire.

CONCLUSIONS

Because goats are commonly thought to be raised by smallholder farmers with limited access to information and resources on better techniques, goat productivity falls short of its potential due to a lack of adequate management practises. Goat farmers' production efficiency is limited by poor breeding, feeding, housing, and treatment. These constraints need to be overcome through either support and a coordinated approach. The study shows that the number of improved practices increased with an increase in a number of goats equivalent to 25 matured goats and decreases after that indicating that smallholder farmers can perform best up to the given production threshold because of a mixed farming system, as smallholder farmers are involved in livestock and crop farming. Instead of " production of mass, " a policy of "production by mass" instead of "production of mass" would be advantageous for better production of

goat rearing among smallholder producers of developing countries who execute a mixed farming system. Farmers need specific training regarding goat farming and initial support from government and/or non-government organizations. Further, since the impact of help from a male in the household was observed on the adoption of improved practices, awareness about gender mainstreaming, and the importance of equally bearing responsibility by both genders to better the household. From this study, it can affirmatively be asserted that cooperative membership can be helpful to change the farmer's behavior in improving management practices and thus help to improve the yield potentiality of goats. Participation in agricultural cooperatives motivates farmers by creating awareness, improving skill through training and providing required input accessibility, and creating we-feeling among members to help each other in society.

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FARMERS' PERCEPTION ON PESTILENCE AND MANAGEMENT OF CHINESE CITRUS FLY, *Bactrocera minax* (ENDERLEIN) (DIPTERA: TEPHRITIDAE) IN CITRUS ORCHARDS OF NEPAL

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ABSTRACT

This study, during period of 2018 and 2019, was conducted with an objective of assessing the farmers' perspective on the pestilence of B. minax on their citrus orchards and following thereby its pest management measures in the selected eight citrus growing districts of Nepal. Respondent citrus growers were male dominated (75.8%) where Brahmin and Chhetri castes (54.3%) were dominantly involved in the citrus cultivation in the survey districts. Only 25.7% respondent citrus growers had above school level education. The highest reported land holding area, 2.35 ha, was in Sankhuwasabha district followed by Dhankuta (1.72 ha) and Syanjya (1.67 ha). According to the respondents, an average of 234.12 mandarin trees in Syanjya, 159.60 sweet orange trees in Sindhuli, 9.68 lemon trees in Sindhuli, and 11.83 lime trees in Gulmi were calculated maximum acreage of different citrus fruit trees by the each citrus grower. Among the cultivated Citrus spp., lemon fruit found to be extremely vulnerable to Chinese citrus fly infestation. Chinese citrus fly's maggot infestation peak in fruits in orchards was observed in October in the citrus crop cycle. Twenty citrus dominated districts in Nepal found to be regularly invaded of Chinese citrus fly in citrus particularly in lemon, sweet orange and mandarin.

Key words: *Bactrocera minax*, citrus, invasion, management, Nepal

INTRODUCTION

Citrus is one of the most important horticultural cash crops in the world, with significant potential for foreign exchange and employment on both domestic and international markets (Adhikari and GC, 2020; Dorji *et al.*, 2016). Citrus, which is one of the Nepal's most popular traditional fruits, is also in great demand for fresh consumption in the local market (Adhikari and Rayamajhi, 2012). It is one of the major fruit crops in Nepal's mid-hill region, contributing to the people's nutrition security and income generation (Adhikari and GC, 2020; Pokhrel, 2011). Different types of citrus fruits are grown in most of the districts in the country, which share 27.3 percent of the total fruit cultivation. Citrus fruits cover about 27,339 hectares of

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land that produce 274,140 mt. in Nepal (MoALD, 2019/20). Among several biotic and abiotic problems which causes citrus decline in Nepal, the Chinese citrus fly (*Bactrocera minax* (Enderlein) is gradually emerging as a threat (Adhikari *et al.*, 2020c; and Bhandari *et al.*, 2017).

The Chinese citrus fly was originated in China and made its way to the eastern Nepal through Bhutan and India (Sikkim and West Bengal) (Adhikari *et al.*, 2019; Acharya and Adhikari, 2019; Adhikari and Joshi, 2019; Xia et. al., 2018). Geographically, this species of fruit fly is found only in China, Bhutan, India (Sikkim and Western Bengal), and Nepal (CABI, 2020). This is one of the most peculiar fruit fly species (Xia et. al., 2018; Wang and Luo, 1995; Chen and Xie, 1955) in citrus orchards as it displays typical characteristics of bigger size robust body than other fruit fly, restricted plant hosts to *Citrus* spp., univoltine life-cycle, winter diapausing pupae, and declining to para-pheromones but readily attracting to protein baits. *B. minax* is a serious pest in citrus-growing areas, causing significant citrus fruit losses in orchards (Rasid *et al.*, 2021). Occasional *B. minax* incurred citrus fruit losses (up to 100 percent) is common in sweet orange orchards in Nepal (Bajracharya, 2010). In course of *B. minax* invasion extending from eastern to western Nepal, it displayed an ominous sweet orange devastation in the sweet orange orchards in Sindhuli district since 2014 (Adhikari and Joshi, 2018) and host range observed on lemon, sweet orange, mandarin and other citrus fruits. This paper reflects the farmers' perception on the nature of pestilence of *B. minax* in their citrus orchards with their present knowledge of fruit fly management.

METHODOLOGY

STUDY AREA

Citrus growing districts of Nepal, namely Bhojpur, Dhankuta, Sankhuwasabha, Sindhuli, Ramechhap, Dolakha, Syangjya and Gulmi were considered for selecting respondent farmers for investigating their perspective on the pestilence of the Chinese citrus fly, *B. minax* in their citrus orchards and management practices against this pest. Physically, Bhojpur, Dhankuta, and Sankhuwasabha districts are located in the hilly region of Province no 1; Sindhuli, Ramechhap, and Dolakha districts are located in the hilly region of Bagmati Province; and Syangjya and Gulmi districts are situated in the hilly region of Gandaki and Lumbini Province respectively Nepal. Particularly, the information on the citrus cultivation status in the survey area presented has been obtained from the response analysis of randomly selected respondent citrus farmers for the data comparision.

SURVEY METHODS

Farmers' understanding on the pestilence of CCF and their indigenous management practices in their citrus orchards were recorded through a priori prepared questionnaire. Citrus fruit growers as respondents (n = 245) from the eight districts were interviewed and their statements were recorded. Respondents from each fruit-producing area were purposefully selected to get the relevant information. The districts were chosen based on the number of active commercial fruit farmers engaged in the citrus cultivation. Officials from the Prime Minister Agriculture Modernization Project, Project Implementation Units, Agriculture Knowledge Centers, National Citrus Research Program, Paripatle, Dhankuta and local level agriculture sections in the individual local governments were consulted to develop list of citrus fruit growers as respondents. Citrus fruit farmers' knowledge, perception, and practices (KPP) on fruit fly pests and their management were assessed using a semi-structured questionnaire with closed and open-ended questions. On years 2018 and 2019, data was collected through face-to-face interviews and orchard visit.

INVASION EXPANSION OF *B. minax*

An attempt was made to assess the status of the invasion and expansion of the Chinese citrus fly, *B. minax*, in the country through the survey, literature review which includes national and international journals, proceedings, reports, newsletters, and books. The Chinese citrus fly intrusion in a district with an occurrence year was presented in a map of the county (Fig 5.).

STATISTICAL ANALYSIS

The descriptive data were managed and analyzed using Microsoft Excel worksheet (version 97-2003) and SPSS 26 software to derive frequencies, percentages, and means to be presented in the tables and figures.

RESULTS AND DISCUSSIONS

SOCIO-DEMOGRAPHIC CHARACTERISTICS OF THE RESPONDENTS

The sex distribution revealed 181 of them (75.8%) being males and 24.2 percent female. Their ethnicity reported to be Brahmin and Chhetri (54.3%), Adibasi and Janajati (42.7%) and Dalit (3.0%). This reflected that the Brahmin and Chettri were largely involved in citrus cultivation. Regarding education level, more than half, 64.5% (156) were educated up to 10th class, 18.4% (45) of respondents were educated upto 12^{th} class. Similarly, the survey showed that 9.8% (26) respondents were illiterates, whereas, 5.9% (15) and 1.4% (3) found to be graduate degree holders and master degree holders, respectively (Table 1). This indicated that very few higher

level educated persons were actively involved in citrus farming among the respondents. Adhikari *et al*. (2021c) reported that a majority of the citrus grower respondents were male (70.0%) and 43.3% being Brahmin in Dailekh district.

Table 1. Demographic information on citrus fruit growers in selected eight districts of Nepal, 2018/19

Demo-graphic factors (n=245)	Frequency	Percent
Sex		
Male	181	75.8
Female	64	24.2
Ethnicity		
Dalit	9	3.0
Aadibasi and Janajati	101	42.7
Brahmin and Chettri	135	54.3
Education level		
Illiterate	26	9.8
School level	156	64.5
Intermediate	45	18.4
Bachelor degree	15	5.9
Master degree	3	1.4

LAND HOLDINGS AND CITRUS CULTIVATION PROFILE

The survey revealed that farmers from Sankhuwasabha district held the highest land area 2.35 ha followed by Dhankuta (1.72 ha) and Syanjya (1.67 ha), whereas, Ramechhap district's respondents held the lowest land area (1.14 ha) (Figure 1). Similarly, respondents in Sankhuwasabha district held the highest land area under crop cultivation (1.97 ha) followed by Syanjya (1.48 ha) and Dhankuta (1.42 ha) while respondents in Dolakha district held the lowest area under cultivation (1.06 ha). Regarding the area under citrus cultivation, respondents in Sindhuli district reportedly held highest acreage (0.67 ha) followed by Ramechhap and Syanjya (0.65 ha each). At the same time, respondents in Bhojpur district found to be having the lowest area under citrus cultivation (0.16 ha) (Fig 1). The average land holding of farmers was 0.53 ha of which sweet orange cultivation occupied 0.37 ha in Sindhuli district (Parajulee *et al*., 2021).

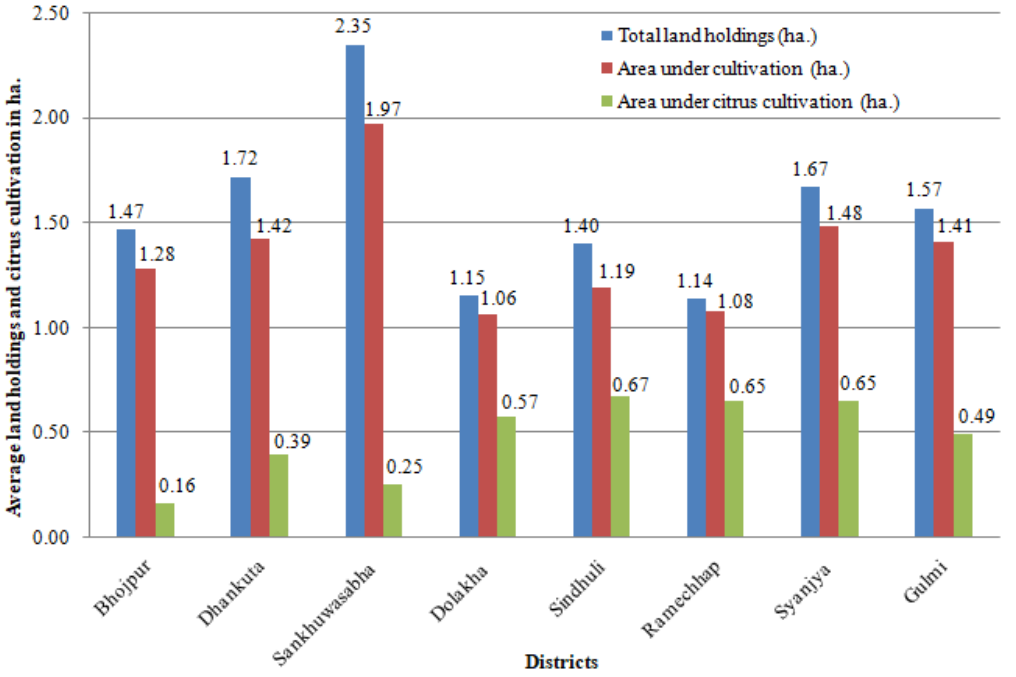

Figure 1. Land holdings and citrus cultivation in selected eight districts of Nepal

INFORMATION ON CITRUS CULTIVATION

Information on citrus cultivation has been presented in Table 2. It showed the highest average total numbers of citrus trees (241.44) and the highest average numbers of productive citrus trees 169.12 (70%) were existed in Syangjya districts. Whereas, the lowest average numbers of citrus trees (56.68) were existed in Bhojpur district, where only 68% were found productive. The maximum numbers of mandarin fruit trees were reported to be 234.12 (97%) in Syanjya, sweet orange 159.60 (70%) and lemon 9.68 (4%) in Sindhuli and lime 11.83 (6%) in Gulmi. Percentage basis citrus cultivation status of each type of citrus fruit among *Citrus* spp. survey revealed that the highest (99%) mandarin cultivation was found in Sankhuwasabha followed by Syangjya (97%) and Gulmi (91%). Similarly, sweet orange covers about 70% of citrus cultivation in Sindhuli followed by 67% in Ramechhap and 6% in Dolakha. Likewise, lemon cultivation was reported highest in Dolakha, Ramechhap, Sindhuli 4% and lime 6% in Gulmi and 5% in Ramechhap and 4% in Sindhuli and Dolakha. In Nepal, Sindhuli district is renowned for the sweet orange orchards while Syanjya district is for mandarin (Table 2). According to MoALD (2019/20), the total area (ha.) and productive area (ha.) of citrus fruits in Bhojpur, Dhankuta, Sankhuwasabha, Sindhuli, Ramechhhap, Dolakha, Syangjya and Gulmi are 1706 (911), 1388 (847), 505 (230), 2463 (1074), 2004 (1121), 443 (220), 1984 (885) and 1137 (693) respectively.

Table 2. Average number of different citrus fruit tree owned by farmers at surveyed districts

Districts*	Bhojpur		Dhankuta		Sankhuwasabha		Dolakha	
Citrus trees	Mean	%	Mean	%	Mean	%	Mean	%
Mandarin	51.76	91	132.76	98	85.48	99	170.60	86
Sweet orange	2.40	4	0.32	0	0.00	0	12.80	6
Lemon	0.80	1	0.76	1	0.60	1	7.80	4
Lime	1.72	3	1.96	1	0.60	1	6.96	4
Total citrus trees	56.68	100	135.80	100	86.68	100	198.16	100
Average productive citrus trees	38.80	68	90.40	67	63.52	73	122.40	62
Districts	Sindhuli		Ramechhap		Syangjya		Gulmi	
Citrus trees	Mean	%	Mean	%	Mean	%	Mean	%
Mandarin	50.48	22	55.00	24	234.12	97	172.72	91
Sweet orange	159.60	70	152.00	67	1.24	1	3.40	2
Lemon	9.68	4	9.44	4	2.04	1	1.68	1
Lime	9.60	4	10.88	5	4.04	2	11.83	6
Total citrus trees	229.36	100	227.32	100	241.44	100	189.16	100
Total productive citrus trees	120.60	53	144.40	64	169.12	70	124.16	66

*Citrus cultivation statistics are derived from 25 respondents in each of the districts.

CHINESE CITRUS FLY (*B. minax)* INCURRED FRUIT DAMAGE

The status of Chinese citrus fly (*B. minax)* incurred fruit damage/loss % in selected eight districts of Nepal in 2018 is presented in the Fig. 2. According to the citrus grower respondents' observations and experience on fruit damage by maggots of the fruit fly in different kinds of citrus fruits, lemon fruit was reported highly prone to Chinese citrus fly followed by sweet orange and mandarin. The respondents of Sankhuwasabha, Dolakha, Syangjya and Gulmi reported a maximum of 95% fruit loss in lemon. Similarly, a maximum of 90% fruit loss in sweet orange was reported from Dolakha and Gulmi, whereas, a maximum of 25% of fruit loss in mandarin was reported from Sankhuwasabha and Dolakha. Dhankuta, Bhojpur, and Khotang districts reported Chinese citrus fly incurred sweet orange losses ranging from 60 to 70% (NCRP, 2006).

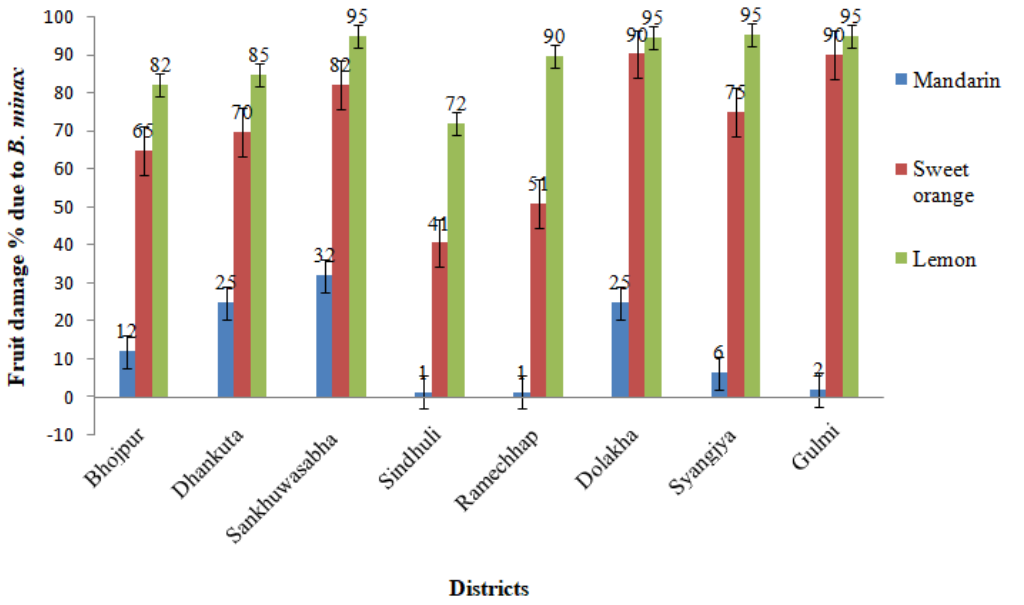

Figure 2. Status of Chinese citrus fly incurred citrus fruit-wise damages as perceived by farmers in surveyed districts of Nepal

SEASONAL FRUIT DAMAGE IN THE ORCHARD DUE TO CFF

Farmers' observations on the extent of fruit damage period at different season in the orchard are shown in Fig. 3. Mostly, the problems of Chinese citrus fly maggots were observed in citrus orchards during September to November. The severity of problem was observed maximum in October at majority of the surveyed districts followed by November and September. A similar life stage and damage pattern of maggot was reported in Sindhuli (Adhikari *et al*., 2021a).

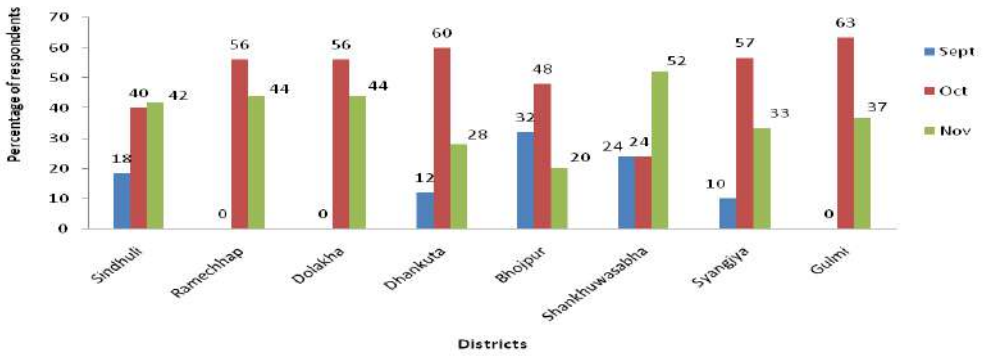

Figure 3. Status of season-wise Chinese citrus fly incurred citrus fruit damages within the citrus crop cycle in surveyed districts of Nepal

KNOWLEDGE OF CITRUS GROWERS ON THE MANAGEMENT MEASURES

Different ten management measures of Chinese citrus fly were asked to assess the knowledge status of respondents in selected eight districts. In all surveyed districts, most of the respondents had know-how on chemical insecticides, orchard sanitation, cultural measures, pheromone lure/trap, botanicals, food/protein bait and exclusion measures (Fig 4). Very few respondents in Sankhuwasabha and Dolakha districts knew the biological measures while a few citrus grower respondents from Bhojpur and Sankhuwasabha districts shared their know-how on post-harvest fruit treatment measures. None of the respondents in districts were aware of sterile insect technique. Obviously, the Chinese citrus fly was never attracted to para-pheromones (Xia et. al., 2018; Wang and Luo, 1995; Chen and Xie, 1955). Hence, application of protein bait as spray on tree and sanitation of infested fruit from orchards as cultural measure were applied in area-wide control program (AWCP) that remarkably achieved success to minimize the fruit loss due to this pest in Sindhuli district (Adhikari *et al.*, 2021b and Adhikari *et al.*, 2020a, 2020b).

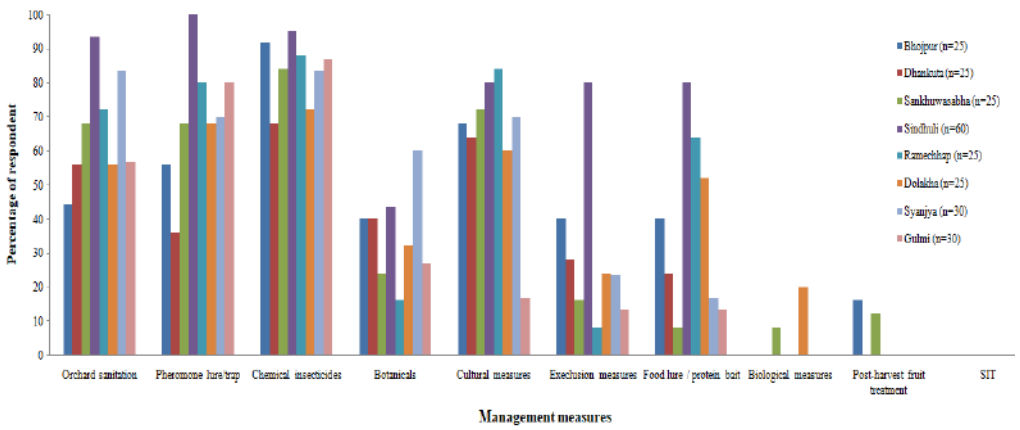

Figure 4. Knowledge status of citrus growers on the management measures of *B. minax*

EXPANSION OF *B. minax* INVASION IN CITRUS ORCHARDS OF NEPAL

The Chinese citrus fly, *Bactrocera minax*, was collected from sweet orange in Helambu, Sindhupalchok district, Nepal in December 1984, which was initially identified as *Bactrocera tsuneonis* (Joshi and Manandhar, 2001). Dr. Gary J. Steck, Curator of Diptera, Florida State Collection of Arthropods, Florida, USA corrected the insect specimen, *Bactrocera tsuneonis* preserved in the National Entomological Research Centre, Nepal Agriculture Research Council, Khumaltar, Lalitpur to *B. minax* (instead the previously identified as *Bactrocera tsuneonis*) on September 26, 2007. Similarly, in the same lot, he identified the fruit fly specimens collected from sweet oranges in Dhankuta on April 27, 2007 to *B. minax* (Poudel *et al*., 2016; Joshi, 2019). Poudel and Regmi (2008) reported the invasion of *B. minax* in sweet orange and lemon in Bhojpur district. National Citrus Research Program (NCRP), Paripatle, Dhankuta in 2014 reported presence of Chinese citrus fly in Myagdi, Gulmi and Parvat districts. Similarly, NCRP (2016) reported citrus fruits infested of similar fruit fly species from Sindhuli, Ramechhap, Solukhumbu districts. In course of progressing survey, Chinese citrus fly maggots infested fruits were observed and reported from Dhankuta, Bhojpur, Sankhuwasabha, Sindhuli, Ramechhap, Dolakha, Syangja, Gulmi, Taplejung, Terhathum, Khotang, Okhaldunga, Kavre, Lamjung, Baglung, Arghakhachi districts. Thus, this study confirmed the invasion of Chinese citrus fly in citrus orchards of twenty districts of Nepal (Fig. 5).

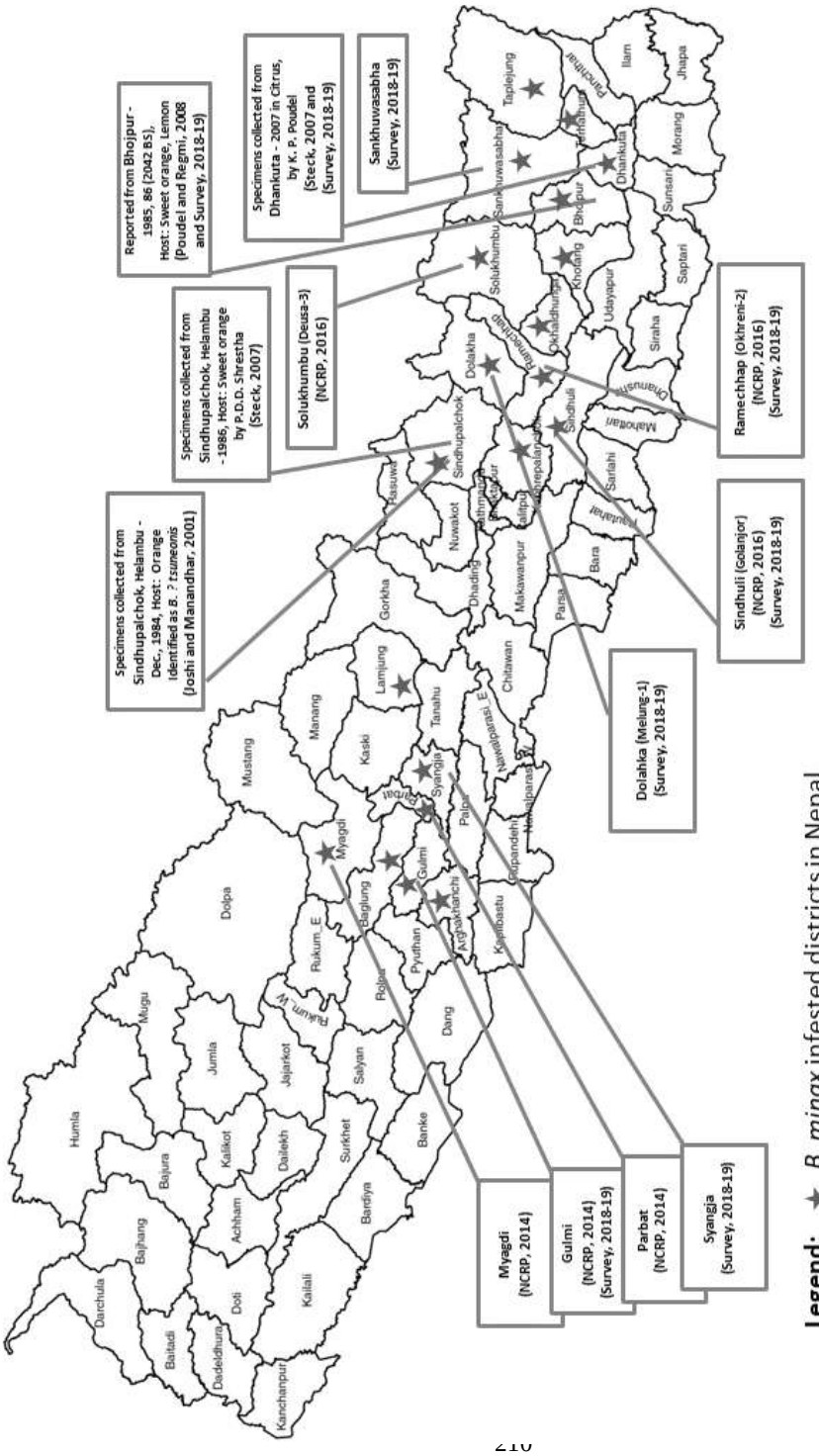

Figure 5. Expansion of invasive Chinese citrus fly in citrus orchards of Nepal

CONCLUSIONS

Respondents were male dominated, 75.8%, and Brahmin and Chhetri castes were dominantly involved, 54.3%, in the citrus cultivation in the survey districts. Among the respondents, only a few higher level educated persons involved in the citrus farming. The highest reported land holding area, 2.35 ha, was in Sankhuwasabha district followed by Dhankuta (1.72 ha) and Syanjya (1.67 ha). According to the respondent citrus growers, the citrus cultivation area in Sindhuli district was highest in acreage (0.67 ha) followed by 0.65 ha in each of Ramechhap and Syanjya districts. Based on the information derived from respondents in each of the districts, among the respondents, a maximum numbers of mandarin fruit trees, 234.12, were found cultivated in Syanjya district, 159.60 sweet orange trees in Sindhuli district, 9.68 lemon trees in Sindhuli district and 11.83 lime trees in Gulmi district. Among *Citrus* spp., lemon fruit reported to be highly prone to the Chinese citrus fly damage. The severity of Chinese citrus fly problem was reported to be highly escalated in October in the crop cycle. Most of the respondent citrus growers had know-how on chemical insecticides, orchard sanitation, cultural measures, pheromone lure/trap, botanicals, food/protein bait and exclusion measures, generally, applied in the fruit fly management. This study confirmed the invasion status of the Chinese citrus fly in citrus orchards of twenty districts in Nepal.

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GOVERNMENT OF NEPAL

MINISTRY OF AGRICULTURE AND LIVESTOCK DEVELOPMENT

SINGHADURBAR, KATHMANDU

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