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Preface

We would like to present, with great pleasure, the inaugural volume-7, Issue-10, October 2021, of a scholarly journal, *International Journal of Environmental & Agriculture Research*. This journal is part of the AD Publications series *in the field of Environmental & Agriculture Research Development*, and is devoted to the gamut of Environmental & Agriculture issues, from theoretical aspects to application-dependent studies and the validation of emerging technologies.

This journal was envisioned and founded to represent the growing needs of Environmental & Agriculture as an emerging and increasingly vital field, now widely recognized as an integral part of scientific and technical investigations. Its mission is to become a voice of the Environmental & Agriculture community, addressing researchers and practitioners in below areas.

Environmental Research:

Environmental science and regulation, Ecotoxicology, Environmental health issues, Atmosphere and climate, Terrestric ecosystems, Aquatic ecosystems, Energy and environment, Marine research, Biodiversity, Pharmaceuticals in the environment, Genetically modified organisms, Biotechnology, Risk assessment, Environment society, Agricultural engineering, Animal science, Agronomy, including plant science, theoretical production ecology, horticulture, plant, breeding, plant fertilization, soil science and all field related to Environmental Research.

Agriculture Research:

Agriculture, Biological engineering, including genetic engineering, microbiology, Environmental impacts of agriculture, forestry, Food science, Husbandry, Irrigation and water management, Land use, Waste management and all fields related to Agriculture.

Each article in this issue provides an example of a concrete industrial application or a case study of the presented methodology to amplify the impact of the contribution. We are very thankful to everybody within that community who supported the idea of creating a new Research with *IJOEAR*. We are certain that this issue will be followed by many others, reporting new developments in the Environment and Agriculture Research Science field. This issue would not have been possible without the great support of the Reviewer, Editorial Board members and also with our Advisory Board Members, and we would like to express our sincere thanks to all of them. We would also like to express our gratitude to the editorial staff of AD Publications, who supported us at every stage of the project. It is our hope that this fine collection of articles will be a valuable resource for *IJOEAR* readers and will stimulate further research into the vibrant area of Environmental & Agriculture Research.

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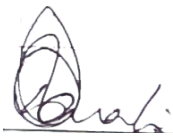
(Managing Editor)



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Mr. Bimal Bahadur Kunwar

He received his Master Degree in Botany from Central Department of Botany, T.U., Kirtipur, Nepal. Currently working as consultant to prepare CCA-DRR Plan for Hariyo Ban Program/CARE in Nepal/GONESA.

Table of Contents

Development of a Disease Prediction Model for Brown Spot Disease severity of Rice based on Weather Variable Parameters

David Kamei[1] and Archana U Singh[2*]

[1]Krishi Vigyan Kendra, ICAR Manipur,
[*2]Division of Nematology, ICAR-IARI, New Delhi
*Corresponding Author

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Abstract— *The correlation studies of brown spot disease incidence of rice with weather factors found that during the first year of studies (2014-15) the disease incidence was significant and negatively correlated with temperature (Tmax.=-.98), (Tmin.=-.93) and wind speed (WS=-.71) whereas others weather factors RHmax, RHmin., Rainfall (RF) were non significant and positively correlated with brown spot disease severity. Therefore, Tmax., Tmin. and Wind speeds are the key weather factors that influenced the brown spot disease severity of Rice. The multiple analysis stepwise equation showed that maximum temperature was found to be an important key factor for brown spot developments during (2014-15) which is supported by highly significant coefficient value of determination also maximum temperature (Tmax.) was found important predictor in case of Propiconazole application and it could be able to explain variation by more than 95% for the Kharif season (2014-15). The value* R^2 *= 0.96 which indicate that the model is fitted well and is good for predicting brown spot incidence providing 95.6% prediction.*

Keywords— Brown spot, Helminthosporium oryzae, Prediction model, weather variable, disease index, correlation, coefficient.

I. INTRODUCTION

A weather base forecasting system is an important aspect that can reduce by optimising the timing and frequency by reducing chemicals usage. The aim of forecasting system is to reduce fungicides use and accurate prediction is important to synchronize the use of disease control measures to avoid crop losses (Taylor *et al.* 2003). A prediction model based on the relationship between environmental conditions at the time of management and late season disease severity could be used to guide management decisions. Thus, if a sound forewarning system is developed, the explosive nature of the disease could be prevented by timely application of control measures. In this regard Multiple Regression Analysis (MRA) approaches are being used to help, synthesize and develop understanding of the complex plant-pathogen-environment relations. The resultant models enable exploration of the factors that govern disease epidemics and the design of control systems that minimize yield losses. The same models have potential to guide breeding programs and work to develop strategies that will prolong the usefulness of disease resistance gene. Thus in the present studies on brown spot disease of Rice prediction models based on weather parameters was developed. Brown spot disease of rice caused by *Heminthosporium oryzae* (Breda de Haan) is a major fungal disease which has been reported to occur in all rice growing countries including Japan, China, Burma, Sri Lanka, Bangladesh, Iran, Africa, South America, Russia, North America, Philipines, Saudi Arabia, Australia, Malaysia and Thailand (Ou, 1985; Khalili, *et al.* 2012). In India the disease was known to occur in all rice growing states but more severe in dry and direct seeded rice in the state of Bihar, Chhatisgarh, Madhya Pradesh, Orissa, Assam, Jharkhand and West Bengal (Gangopadhyay, 1983; Ou, 1985; Ghose *et al*., 1960). This particular disease has been reported to cause enormous losses in grain yield upto 90% particularly when leaf spotting phase assumes epiphytotic proportions as observed in great Bengal famine in 1942 (Ghose *et al.* 1960), in general it can cause yield loss upto 45% when no protection was given. The **w**eather influences all stages of host and brown spot pathogen life cycles as well as the development of disease (Chakrabarty *et al.* 2000). A warning system is previously developed and is being used to schedule fungicide applications for controlling Lettuce downy mildew caused by *Bremia letucae* Regal in coastal California (Scherm *et al.* 1995). The problem,

nature and epidemiologist specific questions determine the mathematical tool to be used for modelling plant disease epidemics (Kranz and Royle, 1978; Sutherst, 1993; Xu, 2006).

II. METHODOLOGY

2.1 In-vivo test:

Field trial was carried out in the experimental plot of Department of Plant Pathology, Allahabad School of Agriculture, SHUATS, Allahabad, U.P., in a consecutive two cropping seasons of Kharif (2014-15) and (2015-16) by using a susceptible Manipur paddy cultivar *viz.*, Daramphou. Field layout were made in Randomized Block Design (RBD) with plot size (2x3) sq. m., a 25 days old seedlings were transplanted with spacing 20 cm (row x row) and 15 cm (plant x plant), with 2-3 seedlings/hill.

2.2 Development of model for weather based prediction system for brown spot disease of rice:

Agrometeorological data was collected from automatic weather station of the Sam Higginbottom University of Agricultural, Technology and Sciences (SHUATS), Allahabad, (U.P.), Central India. Weather factors such as temperature maximum (Tmax.), minimum temperature (Tmin.), Average temperature (Tavge), maximum relative humidity (RHmax.), minimum relative humidity (RHmin.), rainfall (RF) and wind speed (WS) were the parameters taken into consideration for epidemic studies during the period of investigation. The summary of the weather data taken during the period of investigation are presented on following Table 1.

TABLE 1
AGROMATEOROLOGICAL OBSERVATION DURING DISEASE SEVERITY AND EPIDEMIOLOGY STUDIES (2014-15) and (2015-16)

Month	Week	Mean temperature (0^0C)				Relative humidity (%)				Rainfall (mm/hr.)		Wind speed (Km/hr.)	
		2014		2015		2014		2015		2014	2015	2014	2015
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.				
Sept.	4th	36.34	26.71	36.25	27.8	85.5	48.14	90	47.14	0	0.7	1.46	1.73
Sept.	5th	37.6	25.5	36.2	27.8	86	42.5	88.5	53.5	0	0	2.39	1.68
Oct.	1st	35.22	25.02	35.94	27.88	87	47.84	90	48.71	0	0	2.18	1.42
Oct.	2nd	34.65	24.51	35.94	26.71	85.28	60.85	91.57	53.28	109.6	0	1.47	1.31
Oct.	3rd	44.8	28.56	35.28	22.17	78.8	28.8	92.14	50.85	0	0	19.5	0.78
Oct.	4th	32.31	20.22	36.4	20	86.57	54.28	92.42	41.12	0	0	0.57	0.68
Oct.	5th	33.2	20.53	34.93	19.33	85.66	51.66	91.66	52.66	0	4.5	0.55	0.60

Source: Agrometeorological station, SHUATS, Naini, Allahabad, U.P. east, central India.

2.3 Mathematical modelling of cause of epidemic:

2.3.1 Correlation studies:

Correlation measures the degree of association between variables of equal status. There need to be no concept of cause and effect. For calculation of correlation of both dependent and independent variables need to be normally distributed where as for regression this is necessary only for the dependent variables.

2.3.2 Multiple regression analysis studies:

Disease severity variable is being considered as dependable variable and independable variables as weather parameters such as maximum temperature (Tmax.), minimum temperature (Tmin.), Average temperature (Tavge.), maximum relative humidity (Rhmax.), minimum relative humidity (Rhmin.), rainfall (RF) and wind speed (WS) etc. Then stepwise regression equation is used and to obtained desirable results to describe the relationship between dependent and independent variables. The disease severity is called the dependent (response) variable Y and is said to regress on the weather parameters are called the independent (determining) variables X. The application of multiple regression analysis is to join observations of disease data as dependent variable and independent variables on disease development to estimate the change in disease severity

which can be expected from a unit change in these variables and also find out the key factors as predictor for the prediction of the disease severity. For study of the multiple effects on dependent variables, the multiple regression analysis (MRA) was done as a predictive equation. The prediction models and stepwise multiple regression analysis was done by using the following equation.

$$Ý = b_0 + b_1x_1 + b_2x_2 \ldots\ldots\ldots\ldots b_nx_n \quad (1)$$

Where,

Ý = predicted disease severity

b_0 = intercept

b_1b_2 ……b_n= regression co-efficient

x_1x_2……X_n = independent variable

In this equation the regression coefficients (or B coefficients) represent the independent contributions of each independent variable to the prediction of the dependent variable. Another way to express this fact is to say that for example variable X_1 is correlated with the Y variable, after controlling for all other independent variables. SPSS software (SPSS Inc., Chicago,IL) was used to perform multiple regression analysis to develop the disease prediction models where brown spot severity was used as the dependent variable and 10 days average of various weather variable 9 days prior to disease assessment *viz.* max. temp. (X_1), min. temp.(X_2), max. Rh (X_3), mini. Rh.(X_4), rainfall(X_5), Wind speed (X_6) were used as independent variable.

(Machine learning techniques in disease forecasting: a case study on rice bl https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1647291/14 of 22 8/8/2010 7:52 PM)

- **Correlation studies of brown spot of rice with weather factors along with different treatment.**

TABLE 2
CORRELATION STUDY OF BROWN SPOT DISEASE OF RICE WITH WEATHER FACTORS UNDER PROPICONAZOLE TRIAL (2014-15)

Propiconazole	DS	Tmax	Tmin	RF	RHmax	RHmin	WS
DS	1	-.86	-.96	.61	.83	.93	-.33
Tmax	-.86	1	.91	-.56	-.41	-.84	.55
Tmin	-.96	.91	1	-.42	-.69	-.83	.58
RF	.61	-.56	-.42	1	.46	.85	.39
RHmax	.82	-.41	-.69	.46	1	.72	.02
RHmin	.93	-.84	-.83	.85	.72	1	-.07
WS	-.33	.55	.58	.39	.02	-.07	1

Correlation is significant at the 0.05% level

TABLE 3
CORRELATION STUDY OF BROWN SPOT DISEASE OF RICE WITH WEATHER FACTORS UNDER MYCLOBUTANIL TRIAL (2014-15)

Myclobutanil	DS	Tmax	Tmin	RF	RHmax	RHmin	WS
DS	1	-.96*	-.99*	.55	.66	.90	-.49
Tmax	-0.96*	1	.91	-.56	-.41	-.84	.55
Tmin	-0.97*	-.99	.91	1	-.42	-.69	-.83
RF	0.55	.55	-.56	-.42	1	.46	.85
RHmax	0.66	-.41	-.69	.46	1	.72	.02
RHmin	0.89	-.84	-.83	.85	.72	1	-.068
WS	-0.49	-.49	.55	.58	.39	.02	-.068

Correlation is significant at the 0.05% level

TABLE 4

CORRELATION STUDY OF BROWN SPOT DISEASE OF RICE WITH WEATHER FACTORS UNDER PROPINEB TRIAL (2014-15)

Propineb	DS	Tmax	Tmin	RF	RHmax	RHmin	WS
DS	1	-.89	-.95*	.67	.78	.96*	-.31
Tmax	-.89	1	.91	-.56	-.41	-.84	.55
Tmin	-.95*	.91	1	-.420	-.69	-.83	.57
RF	.67	-.56	-.42	1	.46	.85	.391
RHmax	.78	-.41	-.69	.46	1	.72	.022
RHmin	.96*	-.84	-.83	.85	.72	1	-.06
WS	-.31	.55	.58	.39	.02	-.06	1

Correlation is significant at the 0.05% level

TABLE 5

CORRELATION STUDIES OF BROWN SPOT DISEASE OF RICE WITH WEATHER FACTORS UNDER CARBENDAZIM TRIAL (2014-15)

Carbendazim	DS	Tmax	Tmin	RF	RHmax	RHmin	WS
DS	1	-.974	-.889	.721	.513	.935	-.353
Tmax	-.975	1	.912	-.555	-.414	-.840	.549
Tmin	-.889	.912	1	-.420	-.694	-.831	.579
RF	.721	-.555	-.420	1	.461	.851	.391
RHmax	.513	-.414	-.694	.461	1	.722	.022
RHmin	.935	-.840	-.831	.851	.722	1	-.068
WS	-.353	.549	.579	.391	.022	-.068	1

Correlation is significant at the 0.05% level

TABLE 6

CORRELATION STUDY OF BROWN SPOT DISEASE OF RICE WITH WEATHER FACTORS UNDER THIOPHANATE TRIAL (2014-15)

Thiophonate	DS	Tmax	Tmin	RF	RHmax	RHmin	WS
DS	1	-.98*	-.93	.37	.38	.72	-.71
Tmax	-.98	1	.91	-.56	-.41	-.84	.55
Tmin	-.93	.91	1	-.42	-.69	-.83	.58
RF	.37	-.56	-.42	1	.46	.85	.392
RHmax	.38	-.41	-.69	.46	1	.72	-.07
RHmin	.74	-.84	-.83	.85	.72	1	1
WS	-.71	.55	.58	.39	-.07	-.71	1

Correlation is significant at the 0.05% level

TABLE 7

CORRELATION STUDY OF BROWN SPOT DISEASE OF RICE WITH WEATHER FACTORS UNDER CONTROL TRIAL (2014-15).

Control	DS	Tmax	Tmin	RF	RHmax	RHmin	WS
DS	1	-.98*	-.93	.37	.38	.74	-.71
Tmax	-.98*	1	.91	-.56	-.41	-.84	.55
Tmin	-.93	.91	1	-.42	-.69	-.83	.58
RF	.37	-.56	-.42	1	.46	.85	.39
RHmax	.38	-.41	-.69	.46	1	.72	.02
RHmin	.74	-.84	-.83	.85	.72	1	-.07
WS	-.71	.55	.58	.39	.02	-.07	1

Correlation is significant at the 0.05% level

From the data presented in the above Table (2),(3), (4), (5), (6) and (7) revealed that during first year of studies (2014-15), brown spot incidence was significant and negatively correlated with Tmax (r = -.98*), Tmin (r= -.93) and WS (r=-.71) whereas, RHmax (r=0.38) and RHmin (r=0.74) and rainfall (RF = 0.37) which is non significant and positively correlated to brown spot disease severity. Thus, from the present finding, it may be concluded that temperature (Tmax), temperature (Tmin) and Wind speed (WS) are three important weather factors that significantly influenced the severity of brown spot disease of rice. The present findings also supported that as temperature significantly influences the disease progression of brown leaf spot of rice (Dasgupta and Chattopadhyay, 1977). Agrometeorological observation recorded during the studies (Table 1) also supported as reported weather temperature 24°C to 30°C are favourable conditions for disease development (Picco and Rodofil, 2002). Some researchers observed that brown spot incidence is generally not influence with regular rainfall in years (Singh *et al*. 2005). Similarly, in case of our present investigation brown leaf spot disease incidence was found not influenced by rainfall weather factor as shown in the above results data in the years of studies.

- **Development of Prediction Model based on Stepwise Regression Analysis:**

TABLE 8
PREDICTION MODEL/EQUATION FOR BROWN SPOT DISEASE OF RICE BASED ON STEPWISE MULTIPLE REGRESSION ANALYSIS DURING CROP SEASON (2014-15) IN CONTROL PLOT

Sl. No.	Model	R^2	Adjusted R^2
1.	Y= 276.987-7.520*(Tmax)	0.68	0.59
2.	Y= 1559.690-9.407*(Tmax) -14.113*(RHmax)	0 .97	0.96
3.	Y=1669.356-10.635*(Tmax)-14.559*(RHmax)-.575*(RHmin)	0.99	0.99

TABLE 9
PREDICTION MODEL FOR BROWN SPOT DISEASE OF RICE BASED ON STEPWISE MULTIPLE REGRESSION ANALYSIS FOR SELECTED FUNGICIDES TREATMENT DURING CROP SEASON (2014-15)

Sl. No.	Fungicide	Model	R^2	Adjusted R^2
1.	Propiconazole	Y=360.741-13.694(Tmax)	.95	.93
2.	Thiophonate	Y=77.693-2.27(Tmin)	.92	.88
3.	Myclobutanil	Y=82.947-2.256.694(Tmin)	.97	.95
4.	Carbendazim	Y=140.707-5.312(Tmax)	.95	.91

Multiple Regression Analysis based prediction model was most commonly developed for predicting disease incidence. But it is wise to go Stepwise Regression technique in order to determine the contribution of individual variables in brown spot disease prediction model during two years of studies (Table 8 & 9). The weather variables i.e., temperature (Tmax.) and (Tmin.), Relative humidity (RH), and rainfall (RF) had shown significant influence in the disease development. Since, weather factors influence the biology of the pathogen. The key weather variables *viz.*, Maximum temperature, Minimum temperature had shown influencing disease development during the study through Stepwise Regression analysis model. The weather factors contributed 68 to 97 per cent variability in disease development.

Combine weather parameters effect of temperature (Tmax.) and Relative humidity (Rhmin.) was found contributing in disease development with coefficient determination value 0.97%. Similarly Tmax, Rhmin and Rhmax were also found influencing on brown spot disease incidence as indicated by the coefficient determination value (R^2) 0.99%.

Multiple Regression Analysis (MRA) was used when disease severity was taken as dependent factors and weather factors *viz.*, maximum temperature (Tmax.) and minimum temperature (Tmin.), rainfall (RF) and wind speed (WS) determine the effect of an independent factors (weather data) collected from the agrometeorology department for finding disease development (Table 1). The stepwise regression technique was used to obtain prediction model based on significant of coefficient determination value (R^2). However, the weather factors as predictors was undertaken to explain key factor which influences disease incidence. Multiple Regression Analysis Stepwise equation showed that maximum temperature was found to be an important factor for brown spot disease development during (2014-15), which is supported by highly significant coefficient value of determination. The R^2 value was 0.96 suggesting that the model is fitted well. Thus, the model was good for predicting brown spot disease incidence. It means that model could give only 95.6% prediction. The standard error of

estimate was also very low. Only two parameters, minimum temperature and maximum temperature contributed towards the development of predictive model. A multiple regression model has been developed based on study of epidemic of leaf blight in relation to various agrometeorological weather factors (Chattopadhay *et al*. 2005; Singh *et al*. 2008; Sangeetha and Siddharamaiah, 2007). Predictive model was proposed by previous researchers on airborne inoculums subjected as an important variable in model of *Ascochyta blight* (Schoeny *et al*. 2007).

III. CONCLUSION

The correlation studies of disease incidence and the weather factors found that conducive temperature range i.e. minimum (Tmin.) and maximum (Tmax.) influences disease severity was at 20.22ºC-44.8ºC ranges as indicated by the weather factor (temperature) during the years of studies (2014-15). The Multiple regression analysis found maximum temperature was the key weather factors for brown spot disease severity and is also the important predictors in the treatment application that explain the variation for more than 95% during the year of its investigation, 2014-15.

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Socioeconomic determinants and availability of ICT for use among small holder rice farmers in Southeast, Nigeria

Gbughemobi B.O.[1*]; Umebali, E.E.[2]; Nkamigbo, D.C.[3]

Department of Agricultural Economics and Extension, Faculty of Agriculture, Nnamdi Azikiwe University Awka, Anambra State Nigeria.
*Corresponding Author

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Abstract— *The study examined socioeconomic determinants and availability of ICT for use among small holder rice farmers in Southeast, Nigeria. Specifically, it described enterprise characteristics of the farmers, ICT availability to rice farmers, enterprise characteristics and their level of use of ICT. Data were collected with a well-structured questionnaire from 476 randomly selected rice farmers and were analyzed using a combination of analytical tools such as descriptive statistics, Tobit regression, Analysis of variance, correlation and z-test. The result revealed male dominance (61.3%), active age (mean age of 38 years), high percentage of married farmers (65.5%). The mean years of formal education (10 years), mean farming experience was 9 years while the mean household size, farm size and annual income from rice were 5 persons, 11.42 plots, and ₦426, 499.76 respectively. Also, the primary occupation was majorly (64.5%) farmers. The study equally showed that majority (62.0% and 99.7%) of the farmers sampled in Ebonyi and Enugu were members of farmer's cooperative. The result of farmer's response on ICT availability revealed that most of the ICT tools were scarcely available. Tobit regression analysis showed that age, marital status, primary occupation, household size and farm size were significant, while result of significant relationship between the levels of use of ICT tools/format and availability showed a positive and strong relationship with the level of use of ICT. It was recommended that Government and other relevant bodies should ensure that ICT facilities are installed in rural communities and the cost of ICT tools/format and other ICT infrastructures should be subsidized for rice farmers in order to increase their access to information that is beneficial for rice production.*

Keywords— Determinants, use of ICT, rice farmers, Southeast.

I. INTRODUCTION

Agriculture is the engine of growth for most developing countries of the world and also one of the most effective ways to alleviate poverty and hunger (Amungwa and Baye, 2014). It can raise income and improve food security for 80% of the world's poor, who live in rural areas and work mainly in farms (World Bank, 2018). Agriculture in Africa has a massive social and economic footprint; more than 60% of the populations of Sub-Saharan Africa are smallholder farmers, and about 23% of Sub-Saharan Gross Domestic Product (GDP) comes from agriculture (Goedde, Ombaka and Pais, 2019). Agriculture contributed about 22.86% of Nigeria's GDP in 2017 (National Bureau of Statistics (NBS), 2018). These smallholder farmers engage in different livestock and crops production including rice.

Globally, rice production has grown at an annual average of 10% over the past decades, reaching 486.7 million tons in 2017 (NBS, 2018). Most of this growth came from Asia, accounting for 89% of the global output. China and India are the largest producers, each with a share of 29.6% and 22.6% of the global production respectively. Africa accounts for about 4% of world production and the continent is the second-largest consuming region (Abdul-Gafar and Yu, 2016). Nigeria reached a peak of 3.7million tons in 2017 making them the second-largest producer in Africa. Rice is the primary staple food for most of the populace in the region, especially the rural area, with about 6% of global rice consumption. According to Uba (2003), about 70% of Nigeria feeds on rice, while 30% of their cereal-based diets are also from rice. Udemezue (2018) opined that

Nigerians consume 8 million tonnes of rice and the figure rises by 6% annually. Programs, projects, and technologies like Value Addition and Information Communication Technologies (ICTs) have been introduced in rice production and agricultural sector to enhance farmers' agricultural production.

Information Communication Technology (ICT) can be broadly described as the means through which information can be communicated for individual, societal and collective growth of a nation (Ogunyemi, 2010). Information and Communication Technologies (ICTs) are becoming more and more important in connecting farmers and providing information. ICTs helps to keep young people involved in agriculture. The use of ICT becomes imperative among the stakeholders in agriculture, most especially extension workers. ICTs are useful tools and have been exploited by different organizations like Technical Centre for Agricultural and Rural Cooperation (CTA), World Bank and other international organizations to achieve the mission of advancing food and nutritional security in many countries.

ICTs are used to champion practical, cost-effective, and scalable solutions that impact lives. ICTs have a high potential to transform agriculture. They are "means" rather than the "ends". Information and communication technologies (ICTs) could transform agricultural activities in many parts of the world. ICTs contribute to improving youth livelihoods, agricultural modernization and create benefits throughout value chains, especially through increased access to more effective information via many Smartphone apps (Spore, 2019). ICTs also help to strengthen and develop farmers' organizations, especially through social networks.

II. MATERIAL AND METHODS

The study was conducted in Southeast Nigeria. The zone comprises of Imo, Anambra, Abia, Enugu and Ebonyi States. The region is located between latitude $5^{o}45^{'}00^{''}$N and longitude $8^{o}30^{'}00^{''}$E. It is bordered by the Niger River in the west with the total surface area of approximately 76000 square kilometers (29,400sqkm).The region has three types of vegetation. The coastal area in the south is dominated by mangrove swamps and tidal waterways.

Anambra State is located in the South-Eastern part of the country, and comprises 21 Local Government and four agricultural zones to aid planning and rural development. The climate is typically equatorial with two main seasons, the dry and the rainy seasons. It is known for production and marketing of several raw materials and agro products in different parts of the state. Some of the crops produce and marketed in the state include oil palm, maize, rice, yam, groundnut, cassava, garri, cucumber, watermelon, melon, potato, greenbeans (akidi) ,pigeon pea, soyabean and livestock such as fish, goat, sheep, poultry and cattle are also raised (Nkamigbo, Ugwumba and Okeke,2019). It is an agrarian state with high crop production and marketing activities .Majority of the people are subsistence farmers .It is situated on a generally low elevation on the eastern side of the river Niger, sharing boundaries with Delta State to the west Imo, Abia and Rivers States to the south, Enugu state to the East and Kogi State to the North. The state occupies an area of about 4,844km^2. Geographically, the state lies within longitude $5^{0}55^{1}$ and $6^{0}42^{1}$N.The population of the state is 4,182,232 with 863 sqkm density (NPC,2006). The annual rainfall ranges from 1400mm in the North to2500mm in the South with temperature of $25^{o}C - 35^{O}C$.

Ebonyi State is made up of 13 L.G.As with 5533 km^2 as the total landmass and estimated population of 2198371 (NPC 2006). The occupation of the people is predominantly farming with over 80 percent of the population living in rural area and is involved in agricultural production. The vegetation lies between the Rain Forest and Guinea Savannah of Nigeria..

Enugu State is located between latitude 6.5 ($6^{0}30'0$N) and longitude of 7.5 ($7^{0}30'0$E). The state occupies an area of about 8,022,950KM^2 (Ezike, 1998) and has a population of about 3,257,278 (NPC,2006). The state has seventeen (17) Local Government Areas (LGA) and is divided into six (6) agricultural zones namely: Agbani,Awgu, Enugu, Enugu-Ezike, Udi and Nsukka.

2.1 Sampling Technique and sample size

A multi-stage sampling technique was adopted for this study to select 480 respondents among states in Southeast, Nigeria.

Stage 1: This involved purposive selection of three states with a high concentration of rice farmers in Southeast, Nigeria; (Anambra, Enugu and Ebonyi State).

Stage 2: Purposive selection of two (2) agricultural zones from each State making it a total of six (6) zones.

Stage 3: Purposive selection of two (2) Local governments from each of the agricultural zones based on high concentration of rice farmers making it a total of twelve (12) local governments.

Stage 4: Random selection of two (2) communities from each local government making it a total of twenty-four (24) communities.

Finally, twenty (20) rice farmers were selected from each community using the simple random sampling technique. This gave a total sample of four hundred and eighty (480) respondents.

2.2 Method of Data collection and Analysis

Qualitative and quantitative methods were used to collect data from the respondents. Qualitative data were collected using focus group discussion (FGD).The researcher employed the use of Survey CTO which is a powerful, reliable and easy to use survey platform that allows one to at least transport and process data for academic research. Data were analyzed using descriptive analysis such as mean, frequency and percentage, Tobit regression model and inferential statistics (Analysis of variance, Spearman bivariate correlation, and Z-test).

2.3 Measurement of variables

Sex: Sex (dummy, male = 1, female = 0)

Age: Measured in years.

Marital status: single =1, married = 2, widow (er) = 3, separated = 4

Educational qualification: Number of years spent in School

Farming experience = Years

Farm size (Ha)

Household size

Primary occupation

Annual income = (₦)

Membership of a corporative

The level of knowledge of ICT: farmers were asked to tick yes or no to assess their knowledge from the list of statements about ICT. The respondents were allowed multiple responses as they may have more than one knowledge of the subject under discussion. Based on the rule of thumb, level of knowledge is categorized into three as low knowledge with a value of 2, medium knowledge with a value of 4, and high knowledge with a value of 6. A ratio representation of these indicates that variables with percentage value less than 33.3% is low knowledge, while 33.3% to less than 50.0% is medium knowledge, and high knowledge ranges from 50.0% and above.

Attitude of the farmers: The farmers were asked to rate their feelings on ICT, on a 5-point Likert scale of strongly agree (5) agree (4) somewhat agree (3) disagree (2) strongly disagree (1)

Available ICT for use: The respondents were asked to tick from the list of the available ICT provided. The respondents were allowed multiple responses as more than one ICT tools/format maybe available to them.

Level of access to ICT: The farmers were asked to rate their access to available ICT on a 5-point Likert scale. The Likert scale and their corresponding values include highly accessible = 5; accessible = 4, moderately accessible = 3, barely

accessible = 2 and strongly not accessible = 1. The values will be added to get 15, which will be divided by 5 to get a mean score of 3.Variables with a mean score of 3 and above will be regarded as accessible while variables with a mean score less than 3 were regarded as not accessible.

Challenges faced by farmers on the use of ICT: 5- point Likert scale, with options of very serious = 5; serious = 4; somewhat serious = 3; not serious = 2; not a problem = 1. The farmer's rating was subjected to a principal factor analysis (PFA) matrix to ascertain the factor loading.

Level of usage of ICT by the farmers: The farmers were asked to rate their extent of use of ICT available to them on a 5-point Likert scale of very often = 5; often = 4; moderate = 3; rarely = 2 and never used = 1. The values were added to get 15 and divided by 5 to get the mean value of 3 Any variable with a mean score 3 and above was regarded as being used frequently by farmers while variable with a mean score of less than 2 was regarded as not being used frequently.

III. RESULT AND DISCUSSION

3.1 Enterprise Characteristics of Rice Farmers

Enterprise characteristics of rice farmers in Table 1 indicate that majority (61.3%) of the rice farmers in the study area were male, while the rest 39.7% were female. This implies that rice farming in the study area were male dominated; this could be owing to the fact that rice farming is masculine in nature. . This agrees with findings of Efah and Kuye (2015) that recorded more male farmers than females in their study area. The study found out that the greater proportion (31.9%) of the farmers were within the age bracket of 31 – 40 years, while the remaining 27.3%, 26%, 10.1%, 3.4% and 1.3% are within the age bracket of 21 – 30 years, 41 – 50 years, 51 – 60 years, ≤ 20 years and 61 years and above respectively. The mean age was found to be 37.93 (38 years). The implication is that rice farmers in the area are still in their active farm age. At the mean age, the use of ICT is expected to be high. In support of this Ajah and Ajah (2014) opined that rice farming is physically demanding and old age can pose a problem to the cultural operations.

The results also revealed that majority (65.5%) of the farmers were married. Thus, married people dominated rice farming in the area. The cultural practices of rice farming are enormous and require hands, hence the involvement of many married farmers. This agrees with the findings of Agbolahor, Obunyela and Adebowale (2012). The study equally found out that the mean level of education was 10.29 (10 years), this implies that the farmers are fairly literate; the use of ICT is also expected to be high. Kuye and Ettah (2015) stated that the relevance of the literacy level of a farmer to farm productivity and production efficiency. They further pointed that education facilitates farmers understanding of information on credit, use of credit and improved crop technologies. The study revealed that the majority (50.2%) of the respondents had ≤ 5 years farming experience, while the remaining 19.7%, 14.3%, 10.3% and 5.7% had farming experience within the bracket of 6 – 10 years, 16 – 20 years, 21 years and above, and 11 – 15 years respectively. On the average, the farmers have spent 9 years (9.28) in rice farming in the study area. This implies that rice farmers in the area were fairly experienced. The result shows that the majority (64.5%) of the farmers were primarily farmers, while the remaining 22.7%, 7.3% and 5.5% are primarily civil servant, artisans and traders respectively. Table 1 study shows that the majority (62.6%) of the farmers were secondarily traders, while the remaining 17.7%, 15.5% and 4.2% were secondarily farmers, artisans and civil servants respectively. Interestingly, the study revealed that the majority (54.0%) of the farmers had a household size of ≤ 5 persons, while the remaining 39.1% and 6.9% have a household size of 6 – 10 persons and 11 persons and above respectively. The farmers averagely had 6 persons (5.56) as their mean household size. Large household size supplies cheap family labour. This number is capable of reducing the cost incurred for labour in the farm. Greater proportion (48.3%) of the farmers had ≤ 10 plots, while the remaining 26.3%, 15.3% and 10.1% had a farm size of 31 plots and above, 11-20 plots, and 21 - 30 plots respectively. The mean farm size was found to be 11.42 plots. It was measured that 15 plots makes a hectare. This may be as a result of land ownership system in the South East Nigeria, which is predominantly by inheritance. Annual income from rice shows that the majority (56.3%) of the farmers had annual income of ₦350,001 and above, while the remaining 19.3%, 12.0%, 10.1% and 2.3% have annual income within the bracket of 50,001 - 150,000, 250,001 - 350,000, 150,001 - 250,000, and ≤ 50,000 respectively. The mean annual income from rice was found to be ₦426, 499.76.

TABLE 1
DISTRIBUTION OF ENTERPRISE CHARACTERISTICS OF RICE FARMERS (n = 476)

Variable	Frequency	Percentage (%)	Mean
Sex:			
Male	292	61.3	
Female	184	38.7	
Age (years):			
≤ 20	16	3.4	
21 – 30	130	27.3	**37.93**
31 – 40	152	31.9	
41 – 50	124	26.0	
51 – 60	48	10.1	
61 and above	6	1.3	
Marital status			
Single	140	29.4	
Married	312	65.5	
Divorced	24	5.0	
Level of education			
Primary school uncompleted	46	9.7	
Primary school	111	23.3	
W.A.S.C/NECO	156	32.8	**10.29**
HND/B.Sc.	121	25.4	
M.Sc./PhD	42	8.8	
Farming experience (years):			
≤ 5	239	50.2	
6 -10	94	19.7	
11 – 15	27	5.7	**9.28**
16 – 20	67	14.1	
21 and above	49	10.3	
Primary occupation			
Farming	307	64.5	
Trading	26	5.5	
Art and craft	35	7.3	
Civil servant	108	22.7	
Secondary occupation			
Farming	84	17.7	
Trading	298	62.6	
Art and craft	74	15.5	
Civil servant	20	4.2	
Household size			
≤ 5	257	54.0	
6 – 10	186	39.1	**5.56**
11 and above	33	6.9	
Farm size (plot)			
<= 10	230	48.3	
11 – 20	73	15.3	
21 – 30	48	10.1	**11.42**
31 and above	125	26.3	
Annual income from rice (₦)			
≤ 50,000	11	2.3	
50,001 - 150,000	92	19.3	
150,001 - 250,000	48	10.1	**426,499.76**
250,001 - 350,000	57	12.0	
350,001 and above	268	56.3	

Source: Field Survey Data, 2020

3.2 Cooperative Membership State wise

The farmer's cooperative membership was shown in Table 2. The findings revealed that in Anambra State, majority (57.6%) of the respondents were not members of farmer's cooperative, while the rest 42.4% are members. Reverse is the case in Ebonyi State where the study shows that the majority (62.0%) of the respondents were members of farmer's cooperative, while the remaining 38.0% are not. Also, majority (99.7%) of the respondents in Enugu were members of farmers cooperative while the remaining 1.3% was not. This implies that the State with high farmers' cooperatives can easily access government loan, improve more in their farming activities because of mutual group learning.

TABLE 2
DISTRIBUTION OF COOPERATIVE MEMBERSHIP STATE WISE

State	No (0)	Yes (1)	Total
Anambra	57.6	42.4	100
Ebonyi	38.0	62.0	100
Enugu	1.3	99.7	100

Source: Field Survey Data, 2020.

3.3 ICT Availability in the Study Area

The farmer's responses on ICT availability is presented in Table 3. The farmers were allowed multiple responses and were ranked. Thus, the top 10 ICT tools/format available to the rice farmers in the area are; Mobile Phone (Personal GSM), Radio set, Television, Facebook, Short Message Services (SMSs), Internet, E-mail, Whatsapp, Video CD Player, and Digital video Disk (DVD). The Table showed the order of their percentage representation as; 96.8%, 96.4%, 96.4%, 57.1%, 56.3%, 43.5%, 39.5%, 29.4%, 27.1%, and 14.7% respectively. This implies that most of the ICT tools are scarcely available in the study area. This may be as a result of the high cost of the ICT tools considering the economic situation of the country. Cooperative societies in the study area should be encouraged to pull resources together for the procurement of these tools even if they will only be made available for its member's use. This findings collaborates with (Ansari and Pandey, 2013), according to them most ICT tools are not available except mobile phones.

TABLE 3
DISTRIBUTION OF ICT AVAILABILITY IN THE STUDY AREA

Sr. No.	ICT Tools/formats Availability	Frequency	Percentage	Ranking
1.	Radio set	459	96.4	2
2.	Television	459	96.4	2
3.	Facebook	272	57.1	4
4.	Mobile Phone (Personal GSM)	461	96.8	1
5.	Short Message Services (SMSs)	268	56.3	5
6.	CD-ROM	14	2.9	12
7.	Video CD Player	129	27.1	9
8.	Computer System	8	1.7	15
9.	Internet	188	39.5	7
10.	Digital Camera	41	8.6	11
11.	YouTube	13	2.7	14
12.	Multimedia Projector	5	1.1	18
13.	Digital video Disk (DVD)	70	14.7	10
14.	E-mail	207	43.5	6
15.	On-line Magazines	7	1.5	17
16.	GPRS	0	-	19
17.	Whatsapp	140	29.4	8
18.	Instagram	8	1.7	15
19.	Video Conferencing	0	-	19
20.	Tele Conferencing	0	-	19
21.	Robots	0	-	19
22.	Twitter	14	2.9	12
23.	Likee (Online Video posting)	0	-	19
24.	Mixler (Online Radio)	0	-	19

Source: Field Survey Data, 2020.

3.4 Rice farmers' enterprise characteristics and their level of use of ICT

The result of the Tobit regression done to test the significant relationship between enterprise characteristics and level of use of ICT tools/format is presented in Table 4. The Tobit regression from STATA version 14 recorded a Log likelihood of -149.566. The more negative value of the Log-likelihood the better the Tobit result to explain the model. The Likelihood Ratio (LR Chi^2) of 142.75 is significant at probability of 0.01 indicating the model goodness of fit to explain the enterprise characteristic relationship with level of use of ICT tools/format. The Sigma value of 0.84995 shows that the total variation of 85% in the use of ICT tools/format is caused by the rice farmer's enterprise characteristics.

Thus, the Tobit regression is predicted as follows:

Use * = 2.244 - $0.14297X_1$ - $0.04016X_2$ - $0.72259X_3$+ $0.00809X_4$ + $0.01265X_5$ + $0.3487X_6$ + $0.144786X_7$ + $3.65e\text{-}02X_8$ - $2.76e\text{-}08X_9$ + $0.03791X_{10}$.

The coefficients of sex, education, experience, annual income from crops and membership of a cooperative were not significant at 10%, 5% or 1% level of probability. The coefficient of age (0.040) was negative and significant at 5% level of probability. This implies that increase in the age of farmers will reduce their ability to use ICT tools/format by 4.0%. This was expected based on *a-priori* expectation as farmer's willingness to use a technology decrease with an increase in age. The predictive value of marital status was negative and significant at 1% level of probability. This implies that as the number of married farmers increase, their use of ICT tool\format will reduce by 72.2%. This is probably as a result of increased responsibilities. The coefficient of primary occupation was positive and significant at 1% level of probability. This implies that as the farmers switch from main occupation (example farming to trading) will increase their use of ICT by 34.9%. The respondents may have to consult ICT material to learn various farming techniques strange to them as a result of their switch of occupation. The coefficient of household size (0.145) was positive and significant at 1% level of probability. This implies that a unit increase in the number of household people will increase the use of ICT tool\format by 14.5%. This result was expected as extension information may be accessed by any member of the family and brought to the knowledge of others who are later subjected to using it.

The coefficient of farm size (0.003) was positive and significant at 1% level of probability. This implies that a unit increase in the farm size will increase the magnitude of use of ICT tool/format by 0.3% by *a prior* expectation, as the farm size increases farms may needs to consult extension services through ICT tools for better and improved farming. This contradicts the findings of Kabir (2015) who stated that education and farming experience are potential factors of enhancing ICT use. On age and farm size, this agrees with the findings of Barclay (2017). Summarily, the study has been able to establish that the enterprise characteristics influencing the use of ICT tool\format in the area were; age, marital status, primary occupation, household size and farm size.

TABLE 4
RICE FARMERS' ENTERPRISE CHARACTERISTICS AND THEIR LEVEL OF USE OF ICT (n = 476)

ICT use	Coefficient	Std. Err.	t-ratio	P>|t|	Decision
Constant	2.244	0.486	4.62	0.000	
Sex	-0.143	0.185	-0.77	0.440	Accept
Age	-0.040	0.016	-2.45**	0.014	Reject
Marital status	-0.723	0.232	-3.12***	0.002	Reject
Education	0.008	0.025	0.33	0.741	Accept
Experience	0.013	0.017	0.75	0.456	Accept
Primary Occupation	0.349	0.111	3.14***	0.002	Reject
Household size	0.145	0.045	3.25***	0.001	Reject
Farm size	3.65e-02	7.72e-03	4.73***	0.000	Reject
Annual income	-2.76e-08	2.74e-07	0.21	0.920	Accept
Cooperative membership	0.038	0.179	0.21	0.832	Accept
Diagnostic tool					
Sigma	0.850	0.096			
Log likelihood	-149.566				
LR Chi^2	142.75				
Number of obs.	476				

Source: Field Survey Data, 2020. (*) Significant at 10%, (**) Significant at 5%, (***) Significant at 1%.

3.5 Levels of use of ICT tools/format and availability

The result of test on the significant relationship between the levels of use of ICT tools/format and availability is in Table 5. The Pearson Product Moment Correlation (PPMC) for non-parametric tool conducted to test the significant correlation between the level of use of ICT tools/format and availability in the study area was positive and significant at two tailed probability level of 0.01 with an effect size of 0.885**. This result showed a positive and strong relationship with the level of use of ICT tools/format and availability. Based on the two tailed outcome, an increase in one causes 0.885 increases in another and vice versa. This is in line with the findings of (Raghpresad, Gopala and Devaraj, 2016) who opined that knowledge is a key factor in modern agriculture.

TABLE 5
LEVELS OF USE OF ICT TOOLS/FORMAT AND AVAILABILITY (n = 476)

Correlations			Use	Availability
Spearman's rho	Use	Correlation Coefficient	1.000	0.885**
		Sig. (2-tailed)	.	0.000
		N	476	476
	Availability	Correlation Coefficient	0.885**	1.000
		Sig. (2-tailed)	0.000	.
		N	476	476
**. Correlation is significant at the 0.01 level (2-tailed).				

Source: Field Survey Data, 2020. Bivariate correlation matrix

IV. SUMMARY AND CONCLUSION

The study examined the socioeconomic determinants and level of use of ICT among small holder rice farmers in Southeast, Nigeria**.** Data were collected with a well-structured questionnaire from 476 randomly selected rice farmers and were analyzed using a combination of analytical tools such as descriptive statistics, Tobit regression, Analysis of variance, correlation and z-test. The result revealed male dominance (61.3%), active age (mean age of 38 years) and majority (65.5%) of the farmers were married. The mean years spent in formal education was 10 years, mean farming experience was 9 years while the mean household size, farm size and annual income from rice were 5 persons, 11.42 plots, and ₦426,499.76 respectively. Also, the primary occupation was majorly (64.5%) farmers. The study equally showed that majority (62.0% and 99.7%) of the farmers sampled in Ebonyi and Enugu were members of farmer's cooperative.

The result of farmer's response on ICT availability revealed that most of the ICT tools were scarcely available due to high cost of procurement of these tools considering the economic situation of the country.

The result of Tobit regression analysis showed that age, marital status, primary occupation, household size and farm size were significant while the coefficients of sex, education, experience, annual income from crops and membership of a cooperative were not significant at 10%, 5% or 1% level of probability. The result of significant relationship between the levels of use of ICT tools/format and availability showed a positive and strong relationship with the level of use of ICT.

RECOMMENDATION

1. Government and other relevant bodies should ensure that ICT facilities are installed in rural communities.
2. The cost of ICT tools/format and other ICT infrastructures should be subsidized for rice farmers in order to increase their access to information that is beneficial for rice production.

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Gender Analysis on Decision-Making Roles among Maize Farming Households in Agricultural Zone C of Kogi State, Nigeria

Bako Hauwa[1*]; Emmanuel, S. Salau[2]; Haruna, S. Umar[3]

[1]National Space Research Development Agency (NASRDA), Obasanjo Space Centre, Umaru Musa Yardua Express way, P.M.B. 437, Luge, Abuja.

[2,3]Department of Agricultural Economics and Extension Nasarawa State University Keffi, Nigeria

*Corresponding Author

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Abstract— *This study analysed the decision-making role among maize farming households in Agricultural Zone of Kogi state, Nigeria. A multi-stage sampling technique was used to select 160 households from which the male and female heads were interviewed. Data collected were analysed using descriptive statistics and decision-making index. The mean age of male respondents was about 40 years while that of female respondents was about 33 years. Average income of male farmers was N147,321.90 while that of female farmers was ₦143,475.0. The average household size of the respondents was approximately 8 persons. The mean years of experience of male respondents was 16 years while that of the females was 10 years. It was observed that majority (95.9%) of the households depended on inherited land. Male respondents were more dominant in tertiary education than female respondents. The average DMI over all activities was 0.5 meaning that women on the overall were dominated by their men counterparts in terms of decision-making. It was recommended that the female gender must be more involved in households' decision-making as their insights and perspectives can lead to higher productivity. Most constraints identified bothers around institutional and infrastructural inadequacies in Nigeria's rurality therefore better extension service provision should be provided to the rural farmers, higher access to credits and provision of more access roads in rural areas.*

Keywords— Gender, Gender analysis, Gender roles, Decision-making, Households.

I. INTRODUCTION

In Africa, 80% of the agricultural production comes from small-scale farmers, who are mostly rural women. Women comprise the largest percentage of the workforce in the agricultural sector (World Food Organization, 2013). Hence the bridging of the actual and potential productivity gap will promote agricultural productivity and enhance the overall economic development in developing countries like Nigeria. Farmers make decisions on a number of pre-harvest and post-harvest activities such as what to produce, input to use, harvest and post-harvest issues, which according to William (2003) affect production, processing, distribution, prices and costs. Farming decisions are made to maximize farm objectives subject to available materials and human resources. Despite the significant role played by women in agricultural production, processing and marketing in Nigeria (Barasa, 2006) men have continued to dominate farm decision-making, even in areas where women are the largest providers of farm labour (Amaechina, 2002).

Women are more or less relegated to playing second fiddle in farm decision-making. This could be counterproductive because there is bound to be conflict when women as key players, carry out farm tasks without being part of the decision process especially when the decisions fail to recognize their other peculiar household roles and responsibilities (Umeh, 2014). Maize (*Zea mays*) is also known as corn, and belongs to the family of *Gramineae*, which has many characteristics common to other grasses. It is a cereal crop that produces grain that can be used as food for human being as well as animals. Maize is high yielding, easy to produce, readily digested and cheaper than other cereals. It is also a versatile crop (Muhammed *et al*., 2013). Despite the important roles women play in farm and household production, they have not been given due recognition in the agricultural sector (Ingawa, 1999). There has been a great disparity between women and men.

Women have been facing various socioeconomic obstacles such as difficulty in gaining access to land, credit facilities, productivity, enhancing inputs and other services which affect their productivity in agricultural sector compared to men who have more access to productive resources (Rahman, 2009). In most cases women are marginalized in the areas of decision-making as well as access to extension and these have implications to the poverty statuses of women in agrarian economies.

According to United Nation Gender-related Development Index (GDI), women are underprivileged and less empowered and this undeniably restricts women's ability to achieve full potentials in developing countries (United Nation Development Programme, 2006). This study therefore seeks to close the gap of the dearth of information available as to the accurate labour contribution as well as farm decision making roles of women especially in Kogi State. Therefore, the purpose of this study is gender analysis of decision-making roles among maize farming households in Agricultural zone area of Kogi State, Nigeria. The specific objectives of the study are to:

i) Describe the socio-economic characteristics of male and female members of the maize farming households in the study area;

ii) Estimate the level of involvement in farm decision-making by gender among farming households;

iii) Identify the constraints to maize farming in the study area.

II. METHODS AND MATERIALS

The study was conducted in the Agricultural zone area of Kogi state, Nigeria. The zone covers seven (7) Local Government Areas (LGAs) which include Kogi, Lokoja, Adavi, Okene, Okehi, Ajakuta and Ogori Mangogo with its headquarters at Koton-karfe. The study area is located between latitude 6°30^{l}N and8°48^{l}N and longitude 5°23^{l}E and 7°48^{l}E. It has an average annual rain fall of approximately 1,288mm and annual mean temperature range rainfall from 22.7^{o}C– 36.8^{o}C (Agricultural Development Programme [KADP], 2017).

A multi-stage sampling technique was used to select the target respondents. The list of the household maize farmers was drawn from the sampled LGAs to serve as sampling frame for the study. In the first stage, four Local Government Areas (LGAs) were randomly selected from the seven (7) LGAs that make up the Agricultural Zone Area. In the second stage, two villages were purposively sampled from each of the four LGAs based on their level of maize production to give a total of eight (8) villages. Finally, 20 maize farming households were randomly selected from each of the eight (8) selected villages to give a total of 160 maize farming households. From the (160) maize farming households sampled male and female members of the household served as respondents for this study. Thus, a sample size of 160 maize farming households consisting of 160 female and 160 male members given a total of 320 respondents that were used to generate data for this study.

TABLE 1
SAMPLING FRAME FOR MAIZE FARMING HOUSEHOLDS IN THE STUDY AREA

Selected LGAs	Selected villages	Number of registered maize farming households in the villages where both the husband and wife were maize farmers	Number of maize farming households selected in each of villages
Kogi	Girnya Akpogu	65 60	20 20
Lokoja	Banda Abugui	55 53	20 20
Ajaokuta	Ajaokuta Adogo	57 63	20 20
Adavin	Oniyeka Idichegbede	50 62	20 20
Total	**8**	**252**	**160**

Source: Field Survey (2018)

Primary data were collected with the aid of a structured questionnaire that was administered to the respondents. Data were collected on socio-economic characteristics of maize farmers, level of gender involvement in farm decision and constraints to maize farming in the area. Simple descriptive statistics such as percentage, mean, frequency, and count were used to achieve objectives i and iii while Decision Making Index (DMI) was used to analyse objectives ii. Decision Making Index (DMI) and t-test was used to test the hypothesis at 5% level of significant of the study. Formula for t-test value given below as:

$$t = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

2.1 Model specification

Decision Making Index (DMI) as implemented by Rahman *et al*. (2008) and Umar and Luka, (2011) was used. DMI is measured by 3-point scale such as decision taking by female alone (2), decision taking by male and female together (1) and decision taking by male alone (0).

$$DMI = \frac{(M \times 0) + (F \times 2) + (B \times 1)}{Number\ \ of\ respondents}$$

Where:

M=male member of household alone

F =female member of household alone,

B= both male & female members of household.

DMI >1 implies greater involvement in the decision-making process by female farmers.

DMI= 1 shows gender equality in the decision making.

DMI < l indicates greater involvement in the decision-making process by male farmers.

III. RESULTS AND DISCUSSION

3.1 Social-economic characteristics of respondents in the study area.

Figure 1 showed the age distributions of the respondents are presented according to their gender. Results show that most (58.8%) of the male respondents were within the age bracket of 33 – 43 years, followed by 21.3%who were within the age bracket 44-45 years. The mean age of male respondents was 40 years. Results also show that 44.8% of the female respondents were within the age bracket of 22 – 32 years, followed by 44.4% of the female respondents were within the age bracket of 33-43 years. The mean age of female respondents were 33 years. This result implies that respondents in the study area were in their productive ages. Individuals within this age limit are basically the labour force of any sector and are likely to supply labour at its disposition. This agrees with Ogunleye *et al*. (2013) who revealed that individuals within age limit of 21–50 years are basically the labour force of any sector and any side with a greater preponderance of them is more likely to have a greater supply of labour at its disposition.

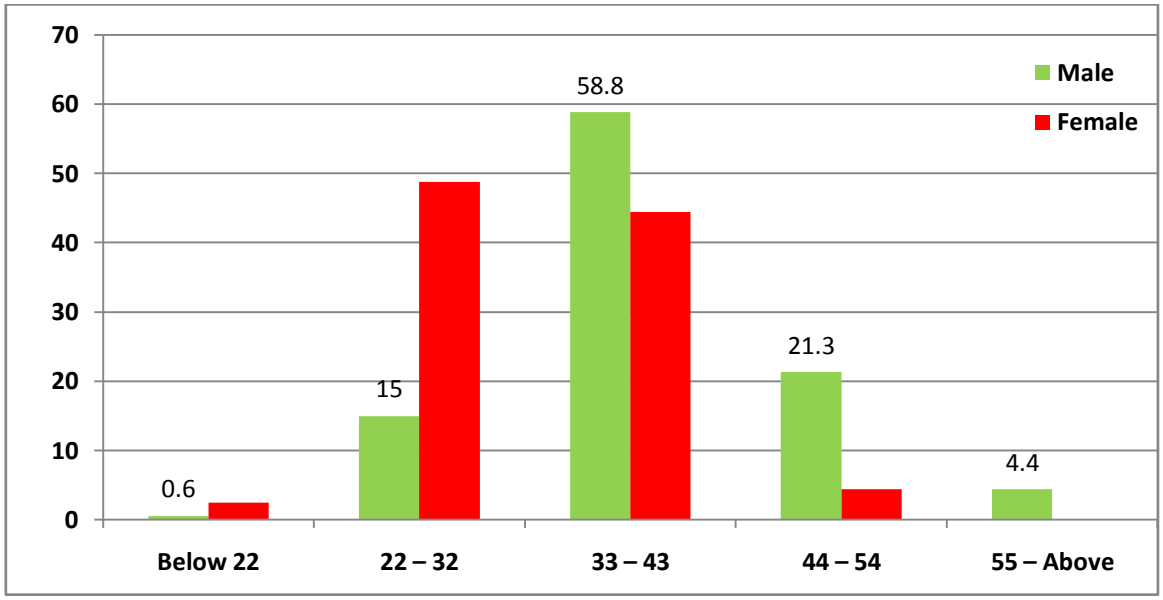

FIGURE 1: Age (years)
Source: field survey, 2018

The distribution of respondents according to their annual income is presented in Figure 2. From the result on the Figure, it is observed that majority (89.4%) of the male respondents earned between N1, 000 and N250, 000 annually. Also, majority (90%) of the female respondents earned N1,000 – 250,000 per annum. Only 10% of the male respondents and 9.4% of the female respondents respectively earned 251,000 – 500,000 per annum. At the highest earning category (Above N1million) only 0.6% of the male respondents earned here while no female respondent was recorded in this category. The mean annual income of male respondents was N147, 321.9 while that of female respondents was N143, 475.0. This implies that the male farmers earned more income than their female counterparts even though both categories were still low-income earners on the average. Analysing the overall income across the two categories it is observed that the mean annual income was N145, 398.40. This implies that the annual income level was generally low among men and women in the maize farming households in the study area. This may be due to their subsistent level of maize production by respondents in the study area. However, the average male income was greater than the average female income. Akpabio, (2005) revealed (74%) of men and women farmers are low income earner. He therefore opined that the poor income level of men and women farmers could be attributed to the subsistence level of farming prevalent in the rural areas.

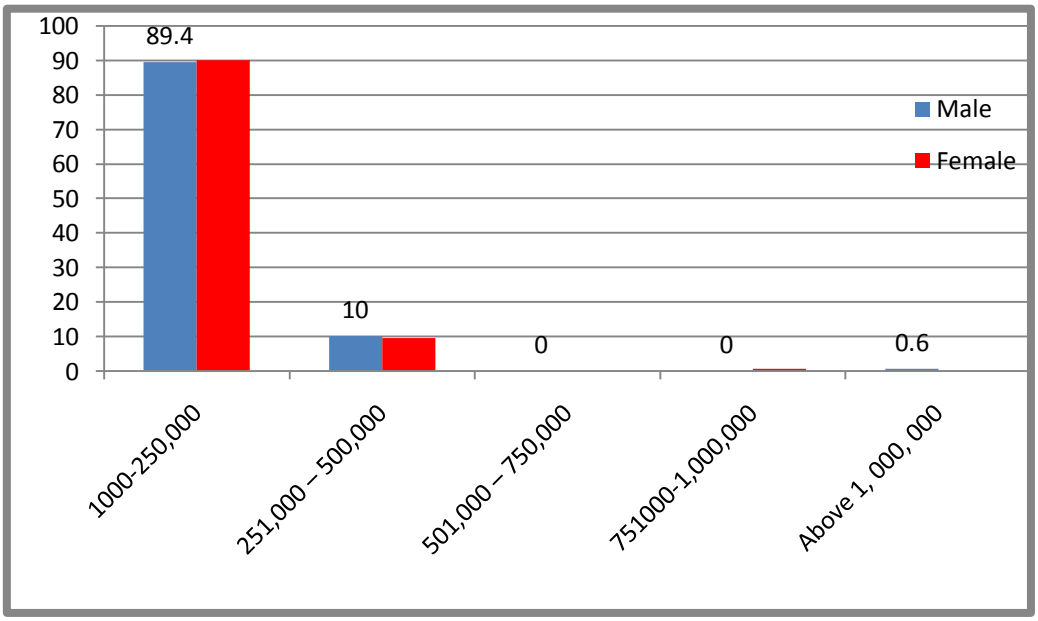

FIGURE 2: Annual income (naira)
Source: field survey, 2018

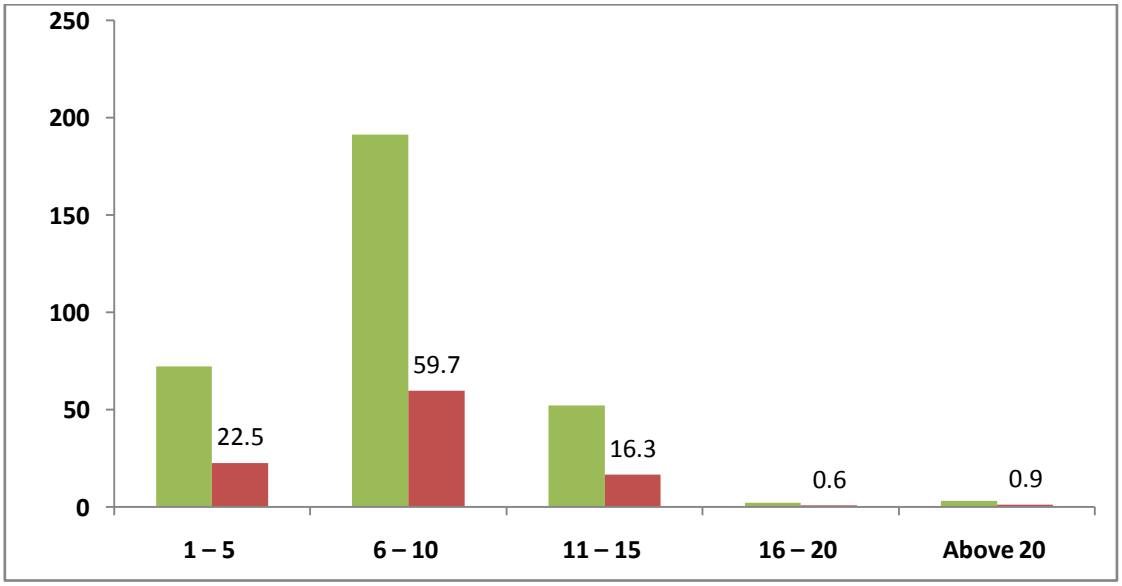

FIGURE 3: Household size (number of persons)
Source: Field survey, 2018

The household sizes of the respondents are presented in Figure 3. From the result on the Figure, most of the respondents (59.7%) had between 6 and 10 persons in their household. Only 22.5% of the respondents had 1 – 5 individuals in their household. Another 16.3% of the respondents had 11 – 15 persons in their household. The average household size of the respondents was approximately 8 persons. However, for the extreme high figures, 0.9% of the respondents had household sizes of over 20 persons. This means that most of the men and women maize farmers in the study area had a fairly large household size which might serve as an insurance against short fall in supply of farm labour. Household size has a great role to play in family labour provision in agricultural sector. Average household size in Nigeria was 5.9 and 4.9 persons in rural and urban areas, respectively as at the research of National Bureau for Statistic (NBS) and Federal Ministry of Agriculture and Rural Development (FMARD), (2016). By this report the average household size of the respondents was almost twice the national average. This results also agrees with Adejoh, *et al.,* (2017) who revealed that majority (60.9%) of male and (64.4%) of female rice farmers had household size between 1-5 members with an average household size of 7 and 5 person respectively implying that there is appreciable number of family labour supply to accomplish various farm operations.

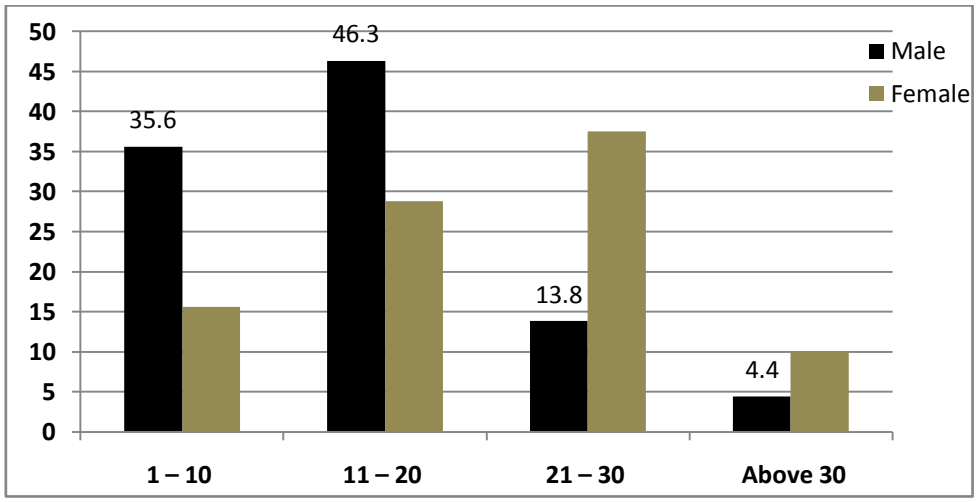

FIGURE 4: Years of Farming Experience
Source: field survey, 2018

The years of farming experience of respondents in the study are presented in Figure 4. A greater proportion (46.3%) of male respondents had between 11-20 years farming experience while majority (70.6%) of female respondents had between 1-10yrs of farming experience. Mean years of farming experience for males was 16years while that of females was 10 years. This implies that male farmers were more experienced in maize farming than their female counterparts. Farming experience is necessary for acquisition of relevant knowledge and skills in maize production. This also has some positive implications for increased production as experience helps to adapt better management decisions. Kagbu *et al.,* (2016) in their study on "Adoption of recommended rice production practices among women rice farmers" in Nasarawa State, Nigeria, revealed that rice farmers were widely experienced matured and could achieve a better understanding of adaptation strategies.

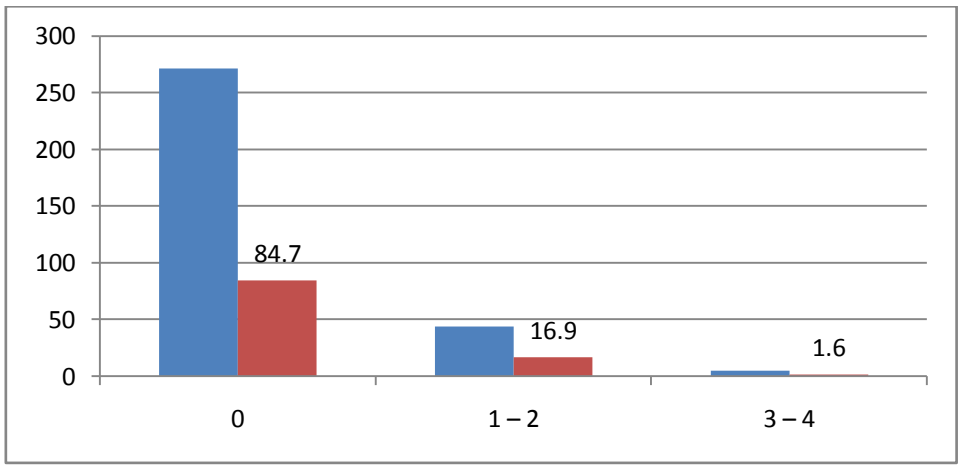

FIGURE 5: Extension Visits (number of times)
Source: field survey, 2018

Figure 5 shows the frequency of extension visits households receive per annum. From the Figure results show that majority (84.7%) of the households did not receive a single visit from extension agents all year round, (16.9%) of the households received between 1 – 2 visits per annum while (1.6%) of the respondents had between 3 – 4 visits per annum. The study revealed that the extension contact was very low in the area, as most of the respondent had never received an extension agent on their farms as a result of poor road network in most of the L.G.A and also most of the villages lacks basic amenities that will attracts any extension agents to wan to visit the place. This implies that extension contact which is supposed to be one of the main sources of agricultural information/ technologies for improved methods of agricultural activities was insufficient in the study area. This may affect the level of maize production as extension agents play critical role in increasing adoption of new farming ideas. According to Adejoh (2017), the provision of agricultural extension can lead to significant yield increases.

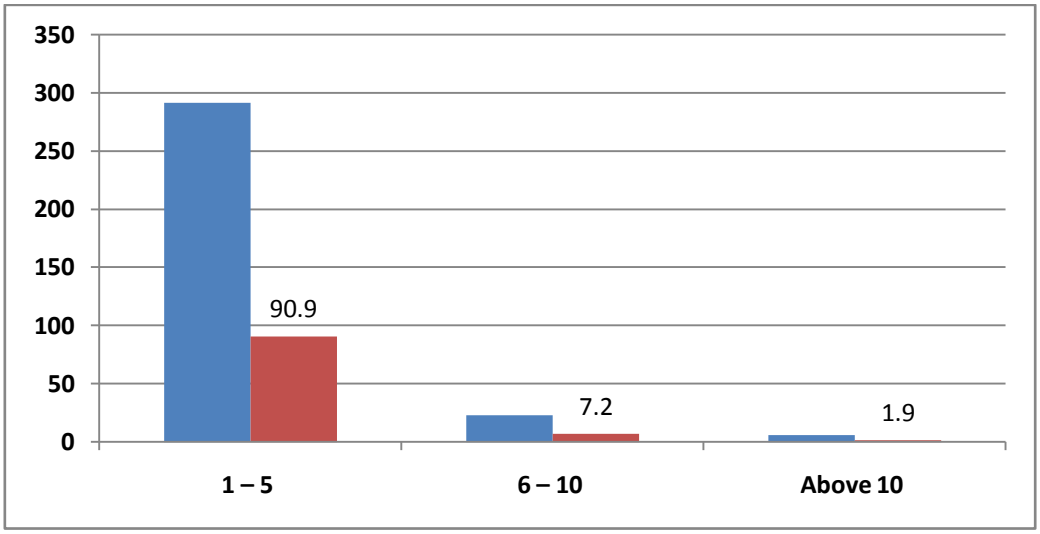

FIGURE 6: Farm size (ha)
Source: field survey, 2018

The sizes of farms are presented in Figure 6. Size of households' fields can give an idea of the amount of labour and other inputs the household may require in carrying out their farm requirements. The result reveals that a resounding majority of the households (90.9%) had land holdings of between 1 – 5 hectares. Another 7.2% of the respondents had between 6 and 10 hectares. Farmers that had above 10 hectares of land were merely 1.9% of the study population. This means that respondents were small-scale farmers in the study area. This may be attributed to the land tenure system prevalent in the study area which encourages small holdings. The size of a farm is a strong determinant of the expected output/yield. This finding is in consonance with assertion of FAO (2010) that 80% of Nigeria's farmers are smallholders.

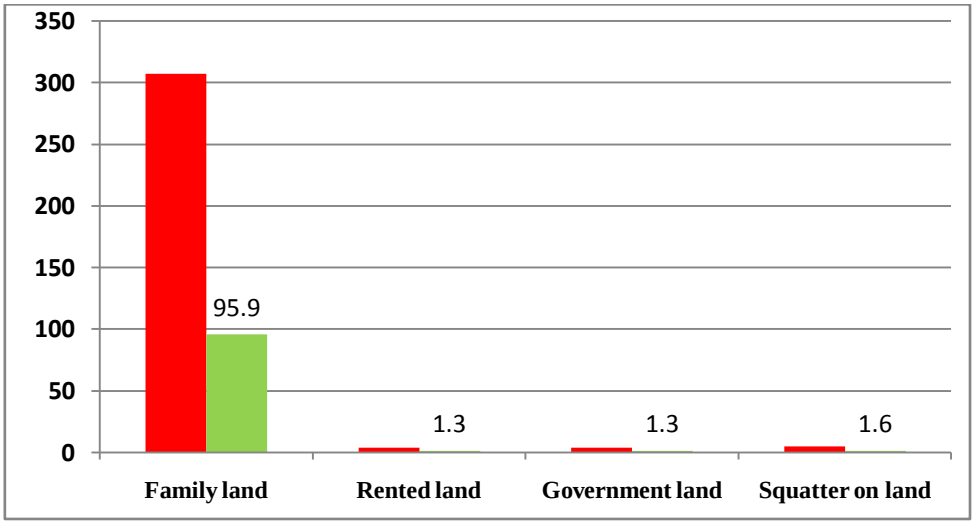

FIGURE 7: Land Acquisition
Source: field survey, 2018

The forms of tenure systems for land acquisition are presented in Figure 7 above. From the result it is observed that majority (95.9%) of the households depended on inherited land as family land for the practice of agricultural production. Squatter land as used by migrant farmers or the extremely impoverished landless people constituted 1.6% of the population. Furthermore, Government land and rented land both constitute 1.3% of land use respectively. This shows that land is acquired through cultural land tenure system in the study area. This may result in women having less access to land and other productive resources as heritage and control of land are given to men in most parts of Nigeria. This agrees with Ajani (2008) who reported that patriarchal structures and authorities give more resources to men in Nigeria, resulting in women having less access to productive resources, particularly land, which is perhaps the most economic constraint for most rural women.

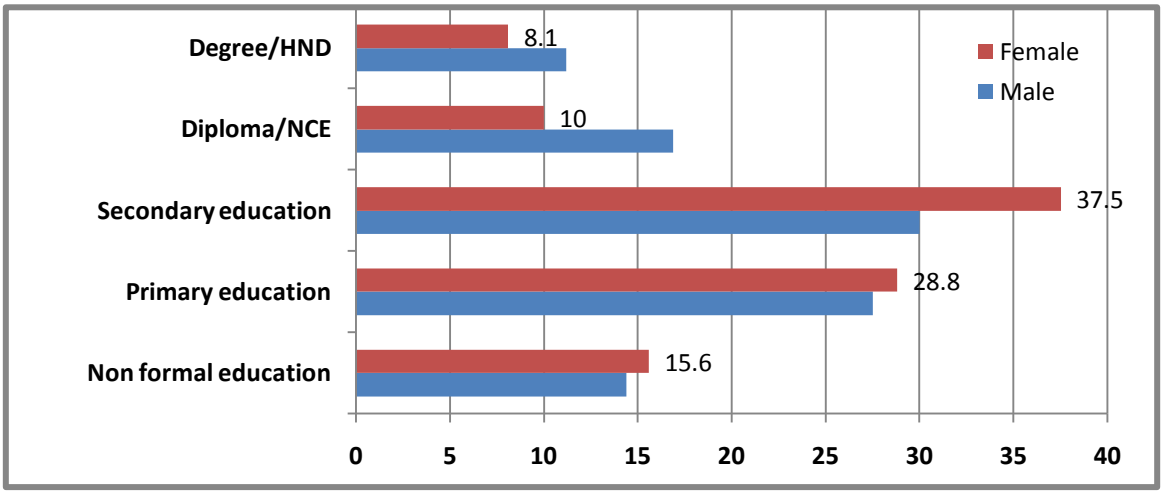

FIGURE 8: Level of Education
Source: field survey, 2018

The different educational qualifications of respondents are presented in Figure 8. From the Table, it is observed that more female respondents (15.6%) had no formal education while 14.4% of male respondents had no formal education. Male and female respondents were close in terms of the percentage of male (27.5%) and female (28.8%) respondents who had acquired primary education although the female respondents were slightly higher. However, more male (30%) and female (37.5%) respondents had secondary education than any other form of education. Male respondents were more dominant in tertiary education than female respondents. For Diploma/NCE holders, 16.9% of male respondents were recorded against 10% of the female respondents while 11.2% of male respondents had acquired Degree/HND against 8.1% of the female respondents. The results implies that (85.6%) of the male respondents had one form of formal education while (84.4%) of the female respondents had one form of formal education. The level of farmers' education is believed to influence the use of improved technology in agriculture and hence, farm productivity. Formal education can influence decision making concerning maize production. This agrees with Kagbu *et al.*, (2016). The results of their findings revealed that about 98 % of the rice producers were literate. These results indicated that rice farmers might have good understanding of improved technologies about rice production, provided they are equally exposed to such technologies.

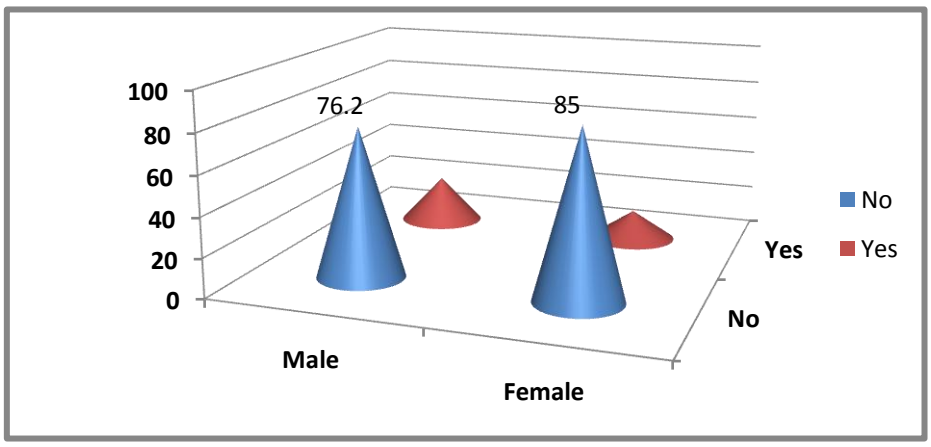

FIGURE 9: Access to credit
Source: field survey, 2018

The results of respondents' accessibility to formal credits are presented in Figure 9. Overall access to agricultural credits was low across both genders. Results show that majority (76.2%) of male respondents had no access to formal credits while only (23.8%) had access to formal credits. Majority (85.0%) of the female respondents had no access to formal credits while only (15.0%) had access to formal credits. The result implies that male respondents had better access to formal credits than their female counterparts in the study area. Access to credit plays a significant role in agricultural production, hence it enable farmers procure inputs such as fertilizers, seeds and agrochemical as well as stimulates adoption of technology in farming and significantly increases farm incomes. This agrees with Ibrahim *et al.*, (2016) who carried out a study on Factors Influencing the Level of Adoption of Cowpea Production Technologies in Askira/Uba Local Government Area of Borno State, Nigeria. Result on access to credit revealed that only 16.9% of the respondents had access to credit. They opined that accessibility to credit warrants farmers procure adoption materials such as improved seeds, fertilizers and chemicals, which will ultimately encourage and enhance adoption of modern farming technology.

3.2 Level of Involvement in the Household Farming Decision

Respondents' level of involvement in maize household farming is shown on Figure 10. Decision-making index is used to analyse respondents' level of involvement in decisions. According to Rahman *et al*. (2008), decision Making Index (DMI) is an important indicator for assessing women empowerment since DMI and women empowerment is positively related. From the result, men were still dominant in decision-making. The observed indicators were selection of enterprise (0.16), input procurement (0.14), input allocation (0.28), selling of produce (0.68), processing of produce (0.94), storing of produce (0.75), consumption (0.78) and choice of innovation (0.25), with all indices less than 1, it means men dominated in decision for all activities. The average DMI over all activities was 0.5 meaning that women on the overall were dominated by their men counterparts in terms of decision-making. This shows that farming enterprise was a male-dominated sector as such the male solely made decisions as regards productive resources and other farm activities that they are dominant in. In most farming communities in Nigeria Women suffered marginalization in decision-making regarding agricultural activities in the household. This agrees with Ajewole *et al.* (2015). In their study, it was observed that the farming enterprise was a male-dominated sector. They also observed that 80.15% of the male had access and solely made decisions as regards productive resources compared to 19.85% of the females. Using the women empowerment index, results showed that women suffered marginalization in decision-making regarding agricultural activities in the households.

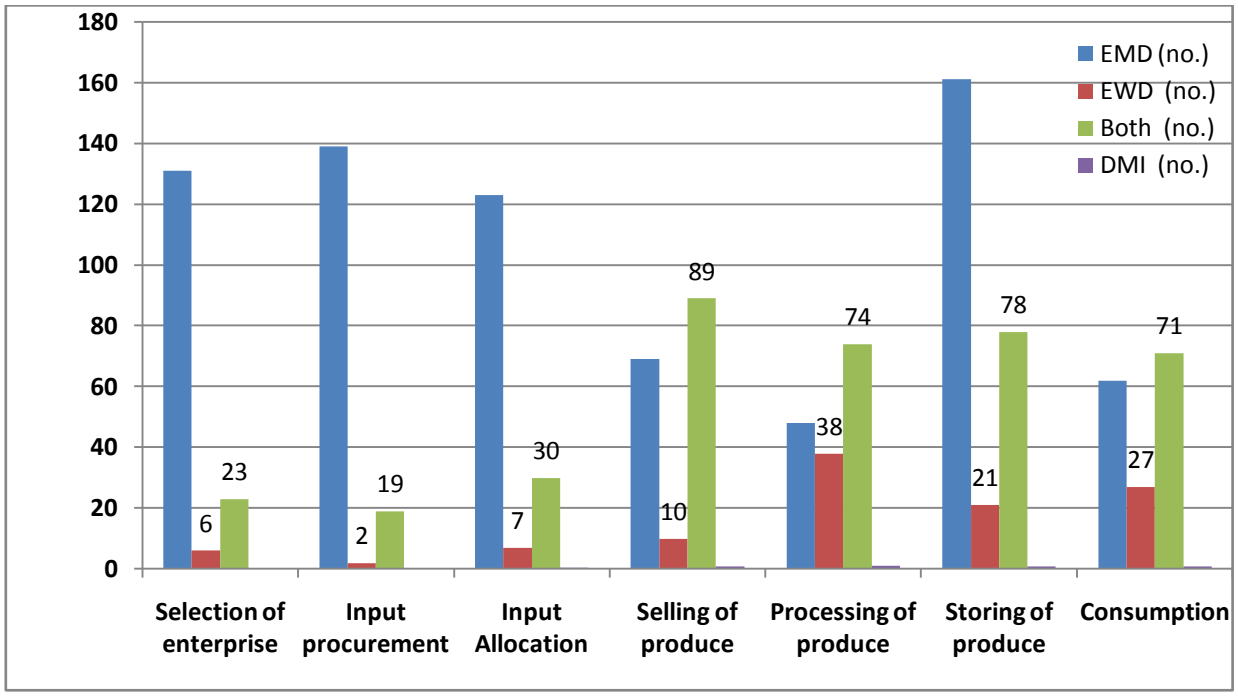

FIGURE 10: Decision Making Index in the Maize Farming Households
Source: Field Survey, 2018

DMA: Decision Making Activities

EMD: Exclusively Men Decision

EWD: Exclusively Women Decision

DMI: Decision Making Index

3.3 Constraints to Maize Production

Respondents' perceived constraints to their production of maize were presented on Figure 11. From the results on the Figure 11 majority (97.5%) of the male respondents perceived inadequacy of extension/advisory services as constraint to maize farming, 95.0% of the male respondents perceived poor access to credit as constraint to maize farming and 91.3% of the male respondents perceived poor access to farm inputs as constraint to maize farming. Also, 88.1% of the male respondents perceived Poor transport systems as constraint to maize farming, 86.3% of the male respondents perceived lack of storage/processing facilities as constraint to maize farming while 59.3% of the male respondents perceived pests and diseases as constraint to maize farming. The results in Figure 11 also show that majority (98.1%) of the female respondents perceived poor access to credit as constraint to maize farming, 97.5% of the female respondents perceived inadequacy of extension/advisory services as constraint to maize farming and 96.3% of the female respondents perceived poor access to farm inputs as constraint to maize farming. Also, 88.1% of the female respondents perceived poor transport systems as constraint to maize farming, 86.3% of the female respondent's perceived lack of storage/processing facilities as constraint to maize farming while 68.1% of the female respondents perceived pests and diseases as constraint to maize farming.

The results implied that male and female maize farmers were faced with multitude of constraints that could reduce their participation in maize production in the study area. Inadequate credit facilities to invest in maize production could reduce the level of participation of farmers in maize production. Poor transport systems imply that farmers in the study area could spend a lot spent a lot of money transporting farm produce to the store and markets. Poor access to farm inputs could constitute a significant constraint to their involvement in maize production. The implication of lack of extension services is that extension services which are supposed to be the main sources of agricultural information/ technologies for improved methods of maize production was lacking completely in the study area. Badmus *et al*. (2015) reported constraints encountered by female maize farmers to include pest infestation, which was the commonest constraint encountered by most women maize farmers, constraints of storage and weather were very common among women maize farmers as substantial number of respondents reported this, problem of glut in the market as well as transportation problem were common to sizeable number of the respondents, other familiar constraints reported were difficulty in getting hired labour (62.5% of the respondents), inadequate fund for production (54.8% of the respondents) and finally difficulty in acquiring land.

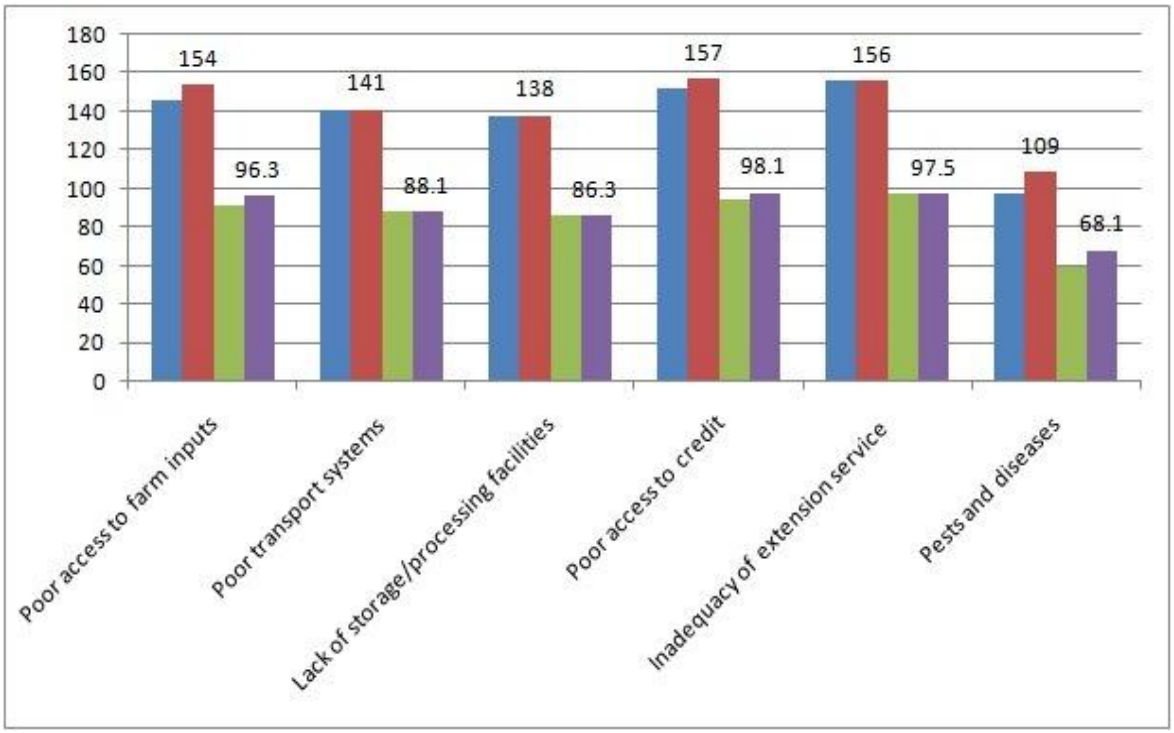

FIGURE 11: Constraints to Respondents' Maize Production

Source: Field Survey, 2018

Multiple responses allowed

3.4 Hypotheses testing

HO: There is no difference between decision making roles among male and female members of the maize farming households.

The null hypothesis stated that there is no difference between decision making roles among male and female members of the maize farming households. The results of the t-test analysis in table 2 below shows that the t-calculated (11.987) was greater than p-value (0.001) implying that there was significant difference between decision making roles among male and female members of the maize farming households. Based on the results the null hypothesis that stated that there is no difference between decision making roles among male and female members of the maize farming households is rejected and re-state that there is significant difference between decision making roles among male and female members of the maize farming households.

TABLE 2
SUMMARY OF THE RESULTS OF THE T-TEST ON DECISION MAKING ROLES AMONG MALE AND FEMALE MEMBERS OF THE MAIZE FARMING HOUSEHOLDS

Source of variance	N	X	SD	Df	t-cal	t-critical	Decision
Male maize farmers man day	160	2.3719	.48328	318	11.987	0.000	Reject
Female maize farmers man day	160	1.7898	.37903				

Source: Field survey, 2018
N = 160, p-<0.05
X= Mean, SD=Standard deviation, Df= Degree of freedom

IV. CONCLUSION AND RECOMMENDATIONS

Based on the findings of this research, it can be concluded that the female gender in the maize farming households was significantly dominated by the male gender in terms of decision-making. The observed indicators in decision-making index show that the men dominated the women in decision-making. This shows that farming enterprise was a male-dominated sector as such the male solely made decisions as regards productive resources and other farm activities that they are dominant in. The study revealed that the extension contact was very low in the area, as most of the respondent had never received an extension agent on their farms. This implies that extension contact which is supposed to be one of the main sources of agricultural information/ technologies for improved methods of agricultural activities was insufficient in the study area.

The female gender must be more involved in households' decision-making as their insights and perspectives can lead to higher productivity. Most constraints identified bother around institutional and infrastructural inadequacies in Nigeria's rurality therefore better extension service provision should be provided to the rural farmers, higher access to credits and provision of more access roads in rural areas.

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Assessment of Factors Responsible for Forest Loss in Tropics

Shailja Tiwari[1], Arpita Awasthi[2], Santosh Agnihotri[3], Sandeep Pandey[4*]

[1]Research Scholar, Department of Botany & Microbiology, Govt. T.R.S. College, Rewa (M.P.), India
[2]Prof. & Head, Department of Botany & Microbiology, Govt. T.R.S. College, Rewa (M.P.), India
[3]Prof. Dept. of Botany, Govt. Science College, Rewa (M.P.), India
[4]Center for Botany, SEB, APS University, Rewa (M.P.), India
*Corresponding Author

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Abstract— *The tropical forest harbors the most enriched and highly diverse ecosystem in the world. Presently, many natural, as well as human-induced activities, are causing a deliberating impact on the biodiversity of this forest. The loss of primary vegetation in these forests has imbalanced the natural cycle of the surrounding environment. Among natural drivers, floods, drought, hurricane, and biotic stresses like pathogen and pest attack, whereas several anthropogenic activities such as forest fire, grazing, land modification through agricultural activities, exploitation of trees for fuel-wood and timber purpose, illegal cutting of vegetation are altogether responsible for massive destruction and degradation of tropical forestry. Various awareness drives has halted the rate of deforestation in last three decades; however, during the same time period, the global area of tropical forest cover has reduced at an alarming rate. In order to restore the loss, there is an urgent need to focus on conservation strategies like habitat rehabilitation, preservation of rare and endangered tree species, application of the new scientific methodology, and most importantly the rehabilitation of barren and waste forest land to ensure the functioning of a forest ecosystem. This research highlights the present status of plant diversity and the main drivers of biodiversity loss in tropical forests.*

Keywords— Tropical forest, biodiversity loss, conservation, habitat rehabilitation.

I. INTRODUCTION

Biodiversity plays a significant role in forest ecosystem functioning and ecosystem services. There exist an important relationship between forest biodiversity and multi-functionality, among ecosystem services. However, the quantitative and causal relationships among forest biodiversity and ecosystem services are not clearly understood (Brockerhoff et al., 2017). Many anthropogenic activities like biodiversity loss, land degradation, and climate change, led to forest modification yet the degree of forest loss is not properly quantified and mapped. According to a study, only 40.5% or 17.4 million km2 of forest exhibit a high level of landscape-level integrity and only 27% of this land area is under protected areas. In these protected areas, only 56% of forests represent a high level of landscape-level integrity. Therefore there is an urgent need to check deforestation and restore natural forests globally (Grantham et al., 2021). The natural processes and forest management should be combined together to control extinctions and restore species richness in degraded lands (Lugo et al., 1993).

Changing climate, rise in temperature, and GHG emission has a great impact on tropical forest biodiversity (Pandey et al., 2016). The tropics have witnessed heavy habitat destruction which may cause a mass extinction in the years ahead. According to a dataset estimation of species richness of 875 ecological samples, about 41% of the tree and animal species are absent from disturbed habitats, however, most of the samples still represent forests of some kind. The homogenization of local communities provides strength to disturbance as losses are partially balanced by gains in these forests (Alroy, 2017).

In tropical forests, the rare plant species coexistence is facilitated by non-random spatial distributions or niche differences, understory plants, and impact of host-specific pests on reproductive adults (Janzen-Connell effects), whereas the established and abundant species are influenced by negative density (Wright,2002). In tropics, the plant diversification is mainly influenced by broad ecological settings as woody plants show contrasting differences in community ecological patterns, population genetic, biogeographic, and phylogenetic. These woody vegetation shows high β-diversity among separate areas of forests, as these areas contain monophyletic clades of endemic plant species with geographically structured intraspecific

genetic variations that are geologically old (Pennington et al., 2009). Major terrestrial biomes like tropical rainforests are biologically enriched and most of their diversity is still unidentified. The traditional and molecular methods help in providing basic information for studying both the origin and management of plant diversity in tropical forests. Modern tools like DNA diagnostic tools, multilocus genomic markers, and plastid "DNA barcodes" can be successfully applied in the taxonomic discovery of tropical forest plots (Dick & Kress., 2009). In the coming years the functional diversity, distribution, and dynamics of tropical trees can be properly addressed using functional genomics (Swenson et al., 2012).

A sampling of rare tropical trees is more challenging due to extensive cryptic diversity. The integration of geography, morphology, and genomics, is a better option for estimation of the species which helps in understanding the origins of diversity and making ease the conservation efforts (Federman et al., 2018). Some of the dimensions of plant diversity like structural, functional, and, taxonomic, show a significant relationship with timber and non-timber forest product (NTFP) services. The richness of tree species in tropics is positively correlated with carbon stocks and as the geographical extent increases there exist a negative correlation with the bonding of this relationship. There should be a strong strategic policy designing on conservation of biodiversity and carbon stocks maintenance at local to regional spatial scales (Steur et al., 2012). The use of a similar technique with some geometric modifications and image mosaicking helps in identifying land cover data and can provide information on forests, plantations, agriculture, non-vegetated, and other land use categories. It also helps in estimating the magnitude of changes in forest cover and assessing of causes of these changes over time (Wijayaa et al., 2015).

Human-induced land modification in the tropics has significantly shown a wide impact on biodiversity and people. Poverty, corruption, environmental apathy, poor natural resource governance, and lack of conservation funding are some of the major challenges in front of conservation biologists. Thus the biologist, civil society, lawyers, social scientists, funding agencies, governments and non-governmental organizations, national and multinational corporations should come forward not only to understand but also to save biodiversity (Sodhi, 2008). In tropical deciduous forests, the rapid inventory information about baseline data of tree species diversity and structure helps in the management of protected areas. This along with in situ methods has the potential in facilitating the conservation of natural forests (Naidu et al., 2018). The forest conservation model requires extensive testing in all forest biomes and geographical regions before implementation (Pandey et al., 2015). The study of the relationship between tree species composition, richness, and carbon stock of tropical dry forest need special attention as it helps in monitoring, predicting, and finding solutions for the management of these ecosystems, often vulnerable to anthropogenic activities. Fine-scale inventory data of tree species has the potentiality in designing predictive models for the effective management of these forests (Sainge et al., 2020).

II. PLANT DIVERSITY OF TROPICAL FORESTS

In tropical deciduous forests the rapid inventory information about baseline data of tree species diversity and structure helps in the management of protected areas. These along with in situ method have potentiality in facilitating the conservation of natural forests (Naidu et al., 2018). In tropical forests the rare plant species coexistence are facilitated by non-random spatial distributions or niche differences, understory plants, and impact of host-specific pests on reproductive adults (Janzen-Connell effects), whereas the established and abundant species are influenced by negative density (Wright, 2002). Forest litterfall enriched in carbon, nitrogen, phosphorus, potassium, calcium improves soil fertility and moisture helping forest recovery and preservation (Pandey et al., 2016). In tropics the plant diversification is mainly influenced by broad ecological settings as woody plants shows a contrasting differences in community ecological patterns, population genetic, biogeographic, and phylogenetic. These woody vegetation shows high β-diversity among separate areas of forests, as these areas contain monophyletic clades of endemic plant species with geographically structured intraspecific genetic variation that are geologically old (Pennington et al., 2009). The soil rich in nutrients favors dense forestation, tree regeneration along with increasing moisture helping germination and seedlings' survival (Singh & Pandey, 2017). Major terrestrial biomes like tropical rainforests are biologically enriched and most of their diversity is still unidentified. The traditional and molecular method helps in providing basic information for studying both the origin and management plant diversity in tropical forest. Modern tools like DNA diagnostic tools, multilocus genomic markers, and plastid "DNA barcodes" can be successfully applied in taxonomic discovery of tropical forest plots (Dick & Kress, 2009). In the coming years the functional diversity, distribution, and dynamics of tropical trees can be properly addressed using functional genomics (Swenson et al., 2012).

The study of relationship between tree species composition, richness, and carbon stock of tropical dry forest need special attention as it helps in monitoring, predicting, and finding solutions for management of these ecosystems, often vulnerable to anthropogenic activities. Fine-scale inventory data of tree species has potentiality in designing predictive models for an

effective management of these forests (Sainge et al., 2020). Forest mapping, modeling, remote sensing, and computer software have the potentiality in studying rare and threatened plant species and their conservation (Pandey et al., 2016). Sampling of rare tropical trees are more challenging due to extensive cryptic diversity. The integration of geography, morphology, and genomics, is a better option for estimation of the species which helps in understanding the origins of diversity and making ease the conservation efforts (Federman et al., 2018). Some of the dimensions of plant diversity like structural, functional, and, taxonomic, show significant relationship with timber and non-timber forest product (NTFP) services. The richness of tree species in tropics is positively correlated with carbon stocks and as the geographical extent increases there exist a negative correlation with the bonding of this relationship. There should be a strong strategic policy designing on conservation of biodiversity and carbon stocks maintenance at local to regional spatial scales (Steur et al., 2012). The use of similar technique with some geometric modifications and image mosaicking helps in identifying land cover data, and can provide information of forests, plantations, agriculture, non-vegetated and other land use categories. It also helps in estimating the magnitude of changes in forest cover and assessment of causes of these changes over time (Wijayaa et al., 2015).

III. FACTORS RESPONSIBLE FOR FOREST BIODIVERSITY LOSS

The continuous loss of biodiversity of global forests in general and tropical forests, in particular, has always remained a matter of serious concern for forest managers. The rapid rate of deforestation is although less than the net loss of forest area, showing a net decline of 4.7 million hectares from 7.8 million hectares per year from 1990 to 2020, or a decrease of 178 million hectares (FAO, 2020). Among various factors, agricultural expansion is the main driver causing deforestation and degradation in tropical forests. In the last 2-3 decades commercial agriculture accounted for 40 % tropical forest loss (FAO, 2020). In the tropics, this activity is of great threat as secondary forests are expanding whereas primary forests are reducing. The maturity and management of planted forests need better understanding. Earlier studies reported continental differences in the diversity due to land-use intensity or differences among species in response to disturbances. The dataset study of tropical countries suggests that species richness in the secondary forest is comparable to primary forest; however, community composition is different in these forests. Compare to other continents, the Asia continent shows a significant difference regarding responses of an individual taxonomic group especially the oil palm plantations, in secondary or planted forests (Phillips et al., 2017). Besides, extraction of wood, fire, drought, grazing and browsing effect and poor management of state government are also the important drivers of deforestation. In warmer regions of the world like North Ethiopia, the dense and open forest account for 83% of forest cover in 1973, which reduced to 39% in 2015 (Hishe et al., 2021). Another important cause of forest loss is illegal harvesting, infrastructure development, and encroachment. The success of Reducing Emissions from Deforestation and Forest Degradation 'REDD+' is based on the identification of these drivers, along with government policies to restructure and reshape the over-dependency on forest resources (Pandey et al., 2013).

The forest loss is a very complex cultural, socio-economic, and political event. The miners, loggers, and rural communities are some of the primary actors responsible for forest exploitation directly causing forest declination. Thus there is a need to understand the main causes such as population growth, distribution of economic and political power, drawbacks in the market system, corruption, and undefined government policies. Accordingly, the introduction of remedial measures should be very specific to fulfill the desired target in due course of time to resolve this complex event (Contreras-Hermosilla, 2000). The loss of tropical forest biodiversity is also attributed to over-exploitation, fragmentation, invasive species, and global climate change causing alteration in species richness and diversity. However, these parameters are not properly addressed on account of their organization and functioning especially in the case of secondary forests and need better understanding and research in the concerned area (Morris, 2010). In some cases the deforestation has also caused an adverse impact on water and an energy resource, however, this impact is not properly estimated. The intensive agricultural practices, illegal lumbering, and growth of human settlements caused the extinction of valuable forest species. The use of geospatial technology based on satellite images helps in better understanding and analyzing the rate of deforestation and impact on forest diversity in these areas (Adeoye and Ayeni, 2011). In some parts of the world as in the Brazilian Atlantic forest the fuel-wood harvesting although an important driver of deforestation has become a necessity for nearly 76% of households residing in 7 rural settlements. In these circumstances, the government has to pay more attention to poverty amelioration along with biodiversity conservation (Specht et al., 2015).

The use of satellite data in the Indonesian forests, the third-largest biome in the globe revealed major information on forest cover and modification during 1990-2012. According to this study, the rate of deforestation declined in 2000-2012 compared to 1990-2000. The major drivers of forest changes in the region reported were subsistence agriculture, plantation forest, and conversion from shrubs/open land, oil palm expansion, and mining. (Wijayaa et al., 2015). The major cause of a decline in

forest structure in Bhutan is selective felling and resource extraction arising due to anthropogenic activities that have created gaps resulting in colonization by non-timber species (Tenzin and Hasenauer, 2016). The biodiversity loss has also affected global carbon concentration in the atmosphere. The deforestation and degradation along with draining and destruction of peat swamp during 1990-2010 in South-East Asia resulted in 60-90% carbon emission; however difficult to be estimated, but during the same period the rate of deforestation declined which is not enough to balance the co2 concentration. The reduction of carbon emission from land, mainly from fossil fuel is a better option in stabilizing carbon concentration in the atmosphere (Houghton, 2012). The loss of trees disturbs the ecological functioning of any forest. The rare tree species loss is of great concern as they possess distinct traits of ecosystem services. This loss cannot be compensated by local species thus there should be both conservations as well as restoration of multifunctional keystone species for ensuring diversity and long-term ecosystem functioning (Tekalign et al., 2017).

IV. CONCLUSION

In conclusion, the loss of tropical wilderness will cause an adverse impact on the natural cycling of environmental components and directly affect the ecosystem functioning of major biomes of the globe. The monitoring of forest area loss using satellite data is urgently required followed by implementing control measures. The weakness in government policies to prevent illegal cutting and trafficking of timber and forest produce should be properly addressed. In situ conservation, conserving keystone species, human population settlement, and other such types of strategies will prevent the loss of valuable species of the tropical forests.

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Assessment of Trees Outside Forests in Rural Region of Varanasi District in U.P.

Anubha Srivastav[1*], Hari Om Shukla[2]

Forest Research Centre for Eco-rehabilitation, Prayagraj
*Corresponding Author

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Abstract— *A study has been undertaken to assess the number of important tree species outside forests in rural areas of district Varanasi. Varanasi is a commercial center and a consumption center for the tree based needs. The species selected were Teak, Mango, Shisham, Mahua, Neem, Aonla and Eucalyptus. These species are very common species as Trees outside Forests (ToF) in rural area of the district. Mango, Neem and Shisham are most demanded species of the region. The district Varanasi has 1277 villages, out of which 12 villages (1 %) were taken for the study. The number of trees on the basis of girth classes was recorded in selected villages of respective blocks. In case of Teak, a total of 272390 trees, in Mango species, a total of 86648 trees, a total of 53116 trees in Neem, in case of Shisham, a total of 23917trees, in Eucalyptus species, a total of 24851 trees, in case of Aonla, a total of 8795 and for Mahua, 16556 trees were enumerated in different girth classes. It was found that Mahua and Aonla trees were very less as compared to other species. Thus, introduction of these species in large areas / private land of farmer may be a viable option for minimizing demand supply gap as well as to increase the tree cover.*

Keywords— Agroforestry, afforestation projects rural region, trees outside forests, timber and firewood species.

I. INTRODUCTION

In India, TOF is defined as all those trees, which has attained 10 cm or more diameter breast height, available on lands, which is not notified as forests. However, FAO defines TOF as trees available on lands which is not defined as 'forests' or 'other wooded land'. Trees outside forests (TOF) in India, mainly growing on private land, are the main source of wood in the country for industry and domestic wood-fuel[1]. These are attracting attention in view of pressure mounting on the existing forests due to increasing population and resource consumption[2]. Unlike forests, TOF are present on all non-forest lands in varying densities and configurations, which makes them a resource rather than an area category[3.] Agroforestry, one of the categorizations under trees outside forests, has immense potential in meeting day-to-day needs and food security of rural population. Trees outside forests are predicted to have a huge role in combating climate change. It is estimated that over 90% of total wood availability for domestic and industrial use now comes from non-forest areas especially from the farm land and some from imports[4.] Trees outside forests occur in natural and in cultivated landscapes and serve in a number of ecological and economic functions [5.] Trees and other woody plants in the landscape serve also important ecological functions, particularly for the conservation of biodiversity, offering shelter and food, and nesting sites [6]; other ecological functions are erosion control, water protection and carbon sequestration. India with its diverse bio-geographical zone and varied agro-climatic conditions presents a unique scenario for the growth of tree species in varying situations. The Trees Outside Forests (TOF) refers to trees on land not defined as forest or other wooded land and generally include trees on farmlands, in cities and human settlements, orchards, roadsides, pastures, banks of river, streams and canals and as shelterbelts which are less than 20m wide and 0.5 ha area [7.] It is now being increasingly argued that the role of TOF in providing food, wood and fuel to rural masses, carbon sequestration, prevention of soil erosion, biodiversity conservation, checking desertification, establishment of wildlife corridors and microclimatic stabilization, is quite substantial[8.] The share of wood energy from non-forest land used for cooking in rural India is 59% while that of biomass energy is 90%[9]. In another study[10], estimated that of the total fuel-wood requirement in India in 1996 (201 Mt), 51% (103 Mt) came from forestlands while the remaining 49% (98 Mt) came from non-forest lands.

Today, Indian agriculture faces diverse challenges and constraints due to growing demographic pressure, increasing food, feed and fodder needs, natural resource degradation and climate change[11]. TOF confined to agricultural lands include tree resources which grow in grasslands and meadows (windbreaks, scattered trees, woodlots, and other silvi- pastoral systems), in amalgamation with annual crops on agricultural fields (cocoa, coffee, and other systems), and trees grown in orchards or along water bodies and permanent crop systems[12]. Therefore, a management system needs to be devised that is capable of producing food from marginal agricultural land and is also capable of maintaining and improving quality of producing environment[13]. Agroforestry system is one of the best known traditional practices and has an important role in reducing vulnerability, increasing resilience of farming systems and buffering households against climate related risks[14], but there are several challenges that reap the benefits of agroforestry in India. The current area under agroforestry in India is estimated as 25.31 million hectares or 8.2 percent of the total reporting geographical area of the country by[11,15,16]. As the population of India is increasing at a very fast rate; the land-holding size of farmers shrink at a very fast rate and agroforestry is the only way to optimize the farm productivity (National Agroforestry Policy, 2014). It is generally well known that status of agroforestry in districts of Eastern plain region of Uttar Pradesh is in developing stage.

India's present forest policy envisages that one third of its geographical area should be covered under forest and plantation. In the state of Uttar Pradesh only 9.20 % (6.15 % forest and 3.05 % Tree cover outside forests) area is covered with trees. The sustainable availability of timber trees in the region of Eastern UP, especially in gangetic plain region is a challenging task. Only 1.11 % forest is in the Varanasi district including tree cover[17]. Thus, present study aims at collecting status of important tree species outside forests (TOFs) in rural areas of the Varanasi district of Eastern Uttar Pradesh with a view to assess the availability of these Trees Outside Forests (TOF) to promote and guide the selection of these species in afforestation programmes by various agencies as well as by local people. This information may be helpful in selection of species while formulating afforestation programmes of U.P. The careful selection of these species in plantations by local people and various agencies will lead to sustainable availability of these species on long term basis.

II. EXPERIMENTAL METHODS

2.1 Study Area

Varanasi is situated in the agro- climatic zone of eastern plain region of Uttar Pradesh, bordering the districts of Jaunpur in the North, Ghazipur in the North East, Chandauli in the East, Mairzapur in the South and Sant Ravidasnagar in the West. The total area of the district is 1535 sq. km, supporting of population of 31.48 lakh persons. This district is densely populated, with 2063 persons per sq. km, as against the state average of 689 persons per sq. km. The urban agglomeration is stretched between 82° 56'E – 83° 03'E and 25° 14'N – 25° 23.5'N. It is located in the middle Ganges valley of North India, along the left crescent-shaped bank of the river Ganges. The river system consists of the mighty Ganga highly revered by Hindus since ages and Gomti, Varuna, Assi, Banganga, Chandra Prabha and Karmnasa are tributaries of the Ganga that drain the area. Being located in the Indo-gangetic plains of North India, the land is very fertile because low level floods in the Ganges continually replenish the soil. There are three main tahsil in Varanasi district. First one is Varanasi, second one is Pindra and another is Rajatalab. There are eight block in Varanasi district. Out of these, there are 03 blocks in Varanasi tahsil namely Chiraigaon, Cholapur and KashiVidyapeeth and partially Harhua and 03 blocks are in Rajatalab tahsil namely Sewapuri, Arajiline and partially Kashi Vidyapeeth and 03 blocks in Pindra tahsil namely Baragaon, Pindra and partially Harhua.

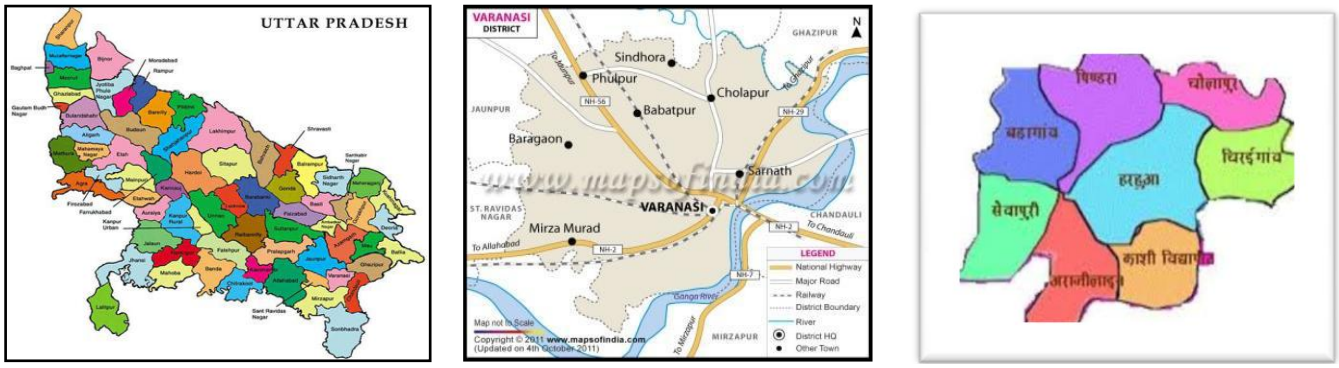


FIGURE 1: Map of Uttar Pradesh and Varanasi district

A study on assessment of important trees outside forests in villages of district Varanasi was conducted in the year 2018-2019. The species selected were Teak (*Tectona grandis*), Shisham (*Dalbergia sissoo*) Mango (*Mangifera indica*), Neem (*Azadirachta indica*), Eucalyptus (*Eucalyptus sp.*),Mahua (*Madhuca longifolia*) and Aonla (*Phyllanthus emblica*). There are 8 developmental blocks in the district and 1277 villages. A total of 1% villages were randomly selected for the study. The methodology adopted for conducting the survey was stratified random sampling to selected villages in respective tehsils. The species wise number of trees on the basis of girth class was recorded in selected villages of respective blocks.

2.2 Sampling Method, Tools And Techniques

1. A questionnaire was prepared and data sheets were field tested in a village. After the field-testing, the necessary changes were added and the data sheets were finalized for collecting information from the study sites. On structured questionnaire, girth class wise recording of trees has been done for selected species.
2. The villagers were assembled in a place as primary school, temple, panchayat etc. and they were asked questions regarding the selected trees that are existing in their village especially on farm bunds, village road side, pond side, homesteads and other locations too. By PRA technique, the villagers were asked to come along with the researchers using transect method for physical verification of species wise trees in the field. In large plantation patches, sampling method was done for recording of data.

2.3 Observations and Calculations

The fieldwork was carried out as per the questionnaire in the selected areas. The observations were grouped on the basis of the 8 block of the district covering 1% of the total villages. In all 8 block, species wise no. of trees were tabulated in respective girth classes *viz.* 0-30, 31-60, 61-90, 91-120, 121-150, 151-180, 181-210, 211-240, 241-270 and 271-300 cm. After combining data of all 8 blocks, the number of TOFs per unit village in rural area of district was assessed. On the basis of per unit village data, assessment for whole rural area of the district has been done for species wise total number of trees. The percent contribution of trees in each girth class was also estimated for respective species[18].

III. RESULTS AND DISCUSSION

The tree species selected for the study were very common as Trees Outside Forests (TOFs) in rural area of Varanasi district. *Mangifera indica, Tectona grandis, Azadirachta indica* and *Dalbergia sissoo* were most demanded species of the region. The total enumerated tree species with respective girth classes in the district has been depicted in Table 1 and Fig. 2 & 3. The results clearly depicted complete picture of enumerated trees of selected species in the villages of different blocks of Varanasi district. The most common tree species of the district included Teak (272390), Mango (86648), Shisham (23917) and Neem (53116), Eucalyptus (24851), Mahua (16556) and Aonla (8795) in different girth classes (Fig. 2).

Maximum Teak trees were found 46.39 % in 31-60 cm girth class, 21.18 % are in 0-30 cm and 24.65 % tree were in 61-90 cm girth class which comes under immature category of timber. Only 7.42 % of the trees and 0.35 % of trees were found in mature category of 91-120 cm and 121-150 cm girth class respectively. It clearly shows that despite of huge demand of Teak wood, its supply position is very limited. Hence, it carries a premium on its price. In present scenario, though its plantation is popular among farmers under agroforestry but more attention is required to be paid to enhance its acceptability by farmers for undertaking extensive plantation. Shisham was found 12.41 % in 0-30 cm, 23.15 % are in 31-60 cm, 37.39 % in 61-90 cm, 20.85 % in 91-120 cm and 6.20 % in 121-150 cm girth class. The results clearly depicted that Shisham plantation is being taken up by the farmers on a regular basis during past years and its girth class distribution is a balanced one. It is second to Teak for timber value in popularity among farmers but farmers are not taking up its plantations in large numbers due to its mortality in water logged conditions.

In case of Mango, 5.80 % trees are in 0-30 cm girth class, 11.32 % are in 31-60 cm, 12.98 % in 61-90 cm, 11.90 % in 91-120 cm, 8.23 % in 121-150 cm, 16.20 % in 151-180 cm, 9.75 % in 181-210 cm, 6.16 % in 211-240 cm, 11.73 % in 241-270 cm and 4.93 % in 271-300 cm girth class. The girth class distribution of Mango is very much wide and villagers are not taking up its plantations in large numbers. The young plantations are of mostly ‘Kalmi’ varieties which cater to the fruit value for

commercial purposes while 'Biju' variety catered to the more fruit value for down trodden, timber, firewood and other intangible benefits. Out of total Neem trees, 21.57 % trees were in 0-30 cm girth class, 19.14 % in 31-60 cm, 26.44 % in 61-90 cm, 19.54 % in 91-120 cm, 9.48 % in 121-150 cm, 0.69% in 151-180 cm girth class. It is clear from the data that young plantations of Neem are not being adopted by the farmers. Out of total Neem trees, 9.54 % trees were in 0-30 cm girth class, 20.49 % in 31-60 cm, 18.46 % in 61-90 cm, 20.81 % in 91-120 cm, 14.28 % in 121-150 cm, 7.11% in 151-180 cm girth classes and other girth classes were in less than 4 % range. It is clear from the data that young plantations of Neem are not being adopted by the farmers.

For Eucalyptus, 18.19 % are found in 0-30 cm girth class, merely 14.63 % in 31-60 cm, 24.15 % in 61-90 cm, 25.54 % in 91-120 cm, 9.78 % in 121-150 cm, 4.41 % in 151-180 cm and 3.30 % in 181-210 cm. girth class. The status of Eucalyptus is very critical in the district. Thus, to maintain sustainable availability of the species in future, its young plantation should be taken up. Likewise, in case of Aonla, 26.10 % trees are in 0-30 cm girth class, 40.04 % in 31-60 cm, 31.39 % in 61-90 cm, and 2.47 % in 91-120 cm. This has created more pressure for fuel wood on timber and fruit species. Its large scale plantation should be taken up.

For Mahua, 0.86 % trees are found in 0-30 cm. girth class, 10.65 % are in 31-60 cm, 9.89 % trees are in 61-90 cm, 11.27 % are in 91-120 cm, 3.66 % trees are in 121-150 cm, 13.95 % in 151-180 cm, 9.31 % in 181-210 cm, 9.65 % in 211-240 cm, 15.51 % in 241-270 cm and 15.25 % in 271- 300 cm. girth class. The girth class distribution of Mahua is very much wide and young plantations are not taking up by the villagers. Mostly trees of Mahua were in old age results also an important species of timber found rare in villages. Majority of the farmers have adopted Teak on their farm bunds as agroforestry species. Most of the Teak trees are too young to be harvested. It is clear from tree enumeration studies that young plantations of Mango, Neem, Mahua and Shisham were less.

In other species category, assessed tree species were Jamun (*Syzygium cumini*), Babool (*Acacia nilotica*), Pani gambhar (*Gmelina arborea*), Kathal (*Artocarpus heterophyllus*), Arjun (*Terminalia arjuna*), Ashok (*Saraca asoka*), and Karanj (*Pongamia pinnata*). These species were not able to fulfill the requirement of wood, but somewhere the amount of firewood used in the daily life of the people was reducing. These species were scattered on the village fallow land and roadside. The total no. of trees come in this category were 65170 and farmers have not adopted such trees with agricultural crops or under agroforestry. A total of 22.40 % plants of this category were under 0-30 cm girth class and 15.15% under 31-60 cm girth class, 17.33% trees in 61-90 cm and 15.77% trees in 91-120 cm. girth class and other girth classes were in less than 15 % range.

TABLE 1
GIRTH CLASS-WISE NUMBER OF TREE SPECIES IN VARANASI DISTRICT

S. No.	Girth class (cm)	Teak	Shisham	Mahua	Eucalyptus	Aonla	Mango	Neem	Others
1	0-30	57679	2968	143	4521	2296	5031	5066	14604
2	31-60	126335	5537	1762	3635	3522	11548	10882	9879
3	61-90	67168	8941	1638	6002	2760	11243	9809	11296
4	91-120	20228	4986	1866	6346	217	9438	11048	10279
5	121-150	980	1485	605	2429	0	7134	7586	3260
6	151-180	0	00	2308	1096	0	14043	3781	3680
7	181-210	0	00	1542	822	0	8447	1642	8187
8	211-240	0	0	1597	0	0	5340	515	2707
9	241-270	0	0	2569	0	0	10165	2117	1190
10	271-300	0	0	2526	0	0	4259	670	88
Total no. of trees		272390	23917	16556	24851	8795	86648	53116	65170

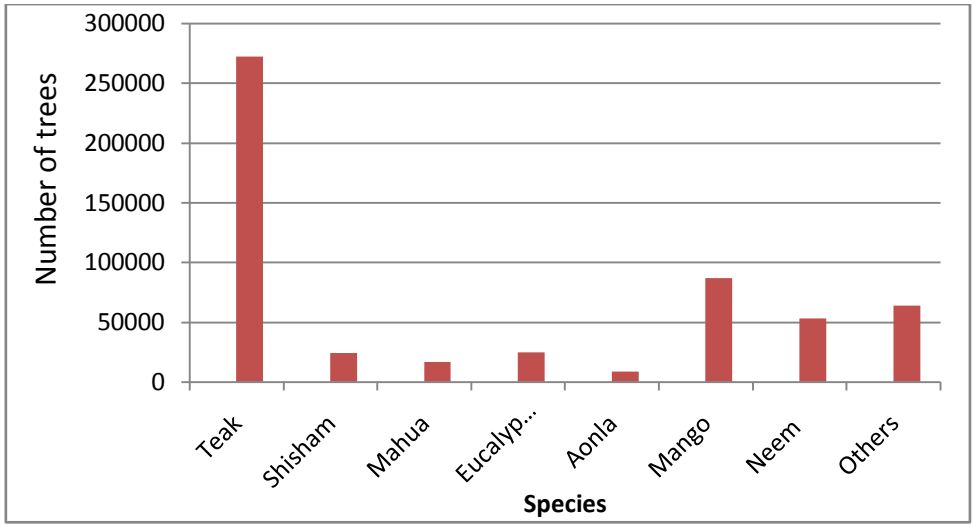
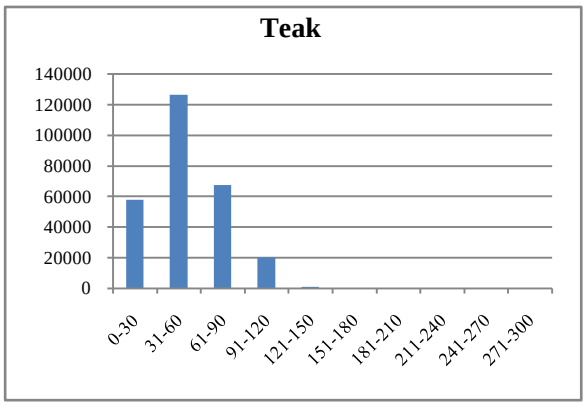
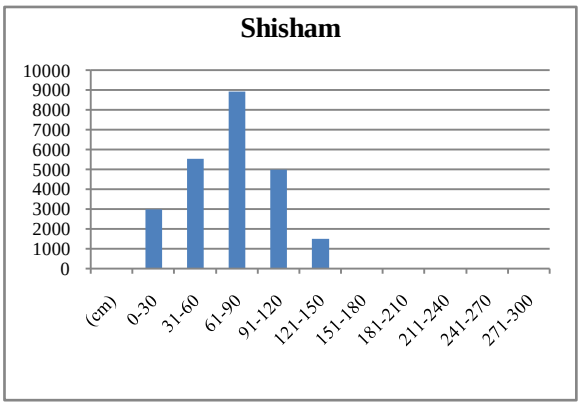
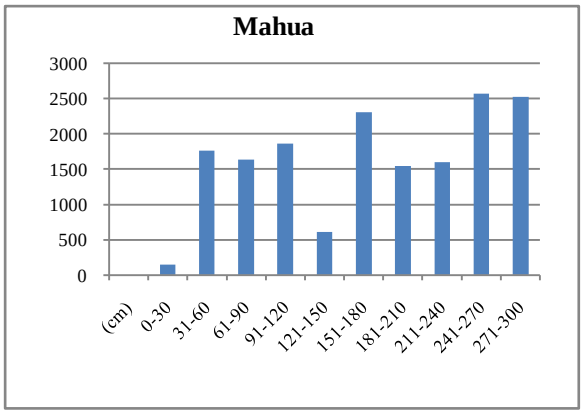
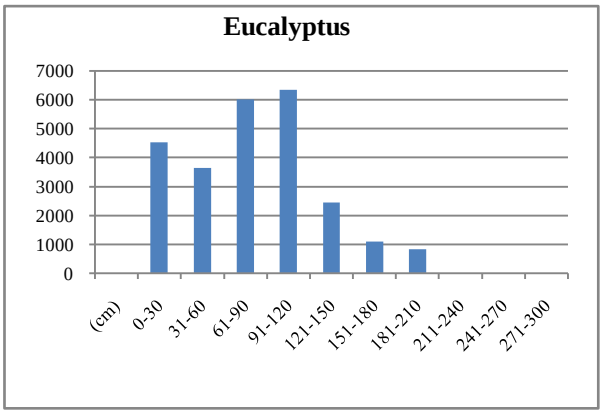


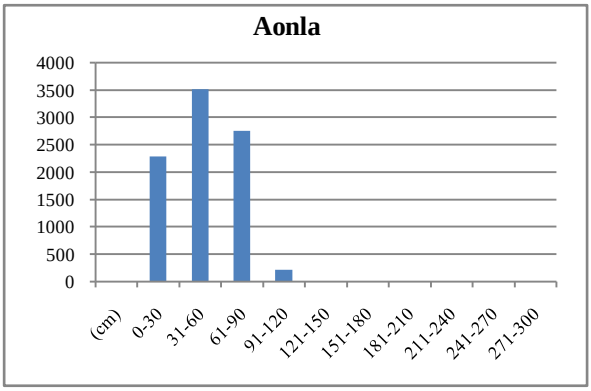
FIGURE 2: Species wise total no. of trees in Varanasi district

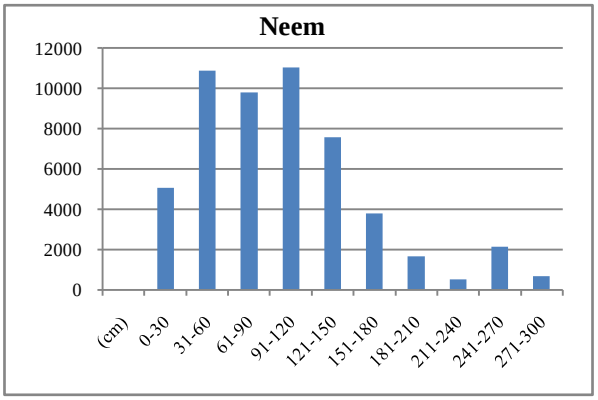












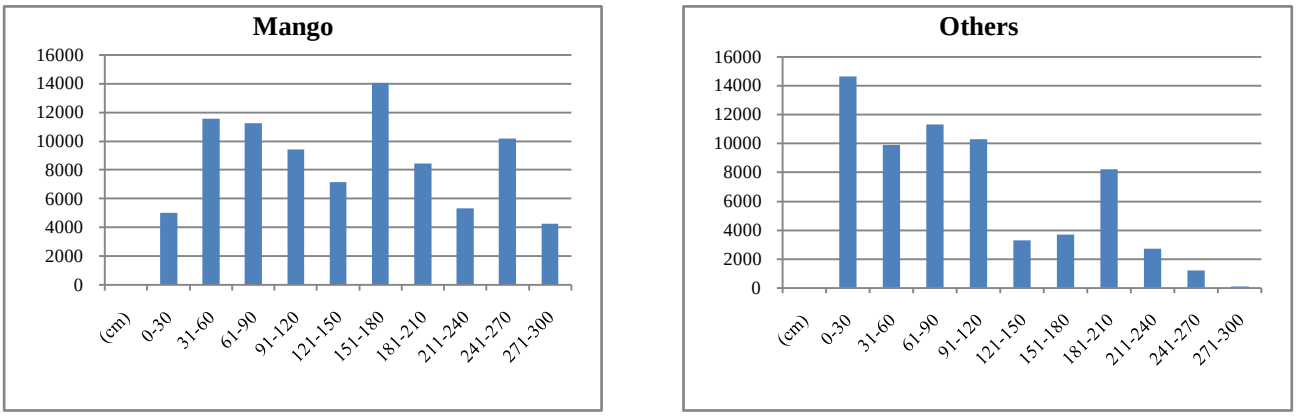


FIGURE 3: Girth - class wise availability of different tree species in Varanasi district

As discussed, the living condition of the surveyed area was very poor. People only consume need based requirements of timber as well as fire wood. They prefer to buy readymade timber articles from the market. In case of consumption of own trees, people sell these trees through contractor or middlemen. Firewood requirement is also in good quantity because alternative sources of energy as gas, stove, cow dung cakes, heater etc. are limited up to a specific class of people. People prefer to buy firewood, kerosene etc. For firewood mostly availability in the market is for mango, Shisham, Neem and Babool. Thinning of trees and market purchase fulfills day to day needs of farmers for firewood.

Mango, Mahua, Teak and Neem were most demanded species for timber. In Varanasi district, demand supply gap is high. The existing trees in 0-30 cm girth class are less for most of the species and needs to be planted in agroforestry and other afforestation programmes. The scenario in Varanasi district has improved much in last ten years. The matured trees of demanded species are also very less in the district. The tree harvesting and sale methods of timber were not much known to villagers and needed to be extended during future extension and trainings. At present, Teak is most demanded timber species besides Mango and Neem. Actually, deshi trees of Mango are very less in villages and for timber it is demanded but for fruits, purposes, kalmi variety is in more demand. The systematic planting of trees on bunds / blocks were less. In district Varanasi, great demand supply gap exists for most of the tree species. The availability of quality planting material, maintenance and management of plantations and sale of timber produce with good returns were major hurdles in the way of success in adoption of agroforestry in Varanasi district.

It is clear that Farmers have common practice to integrate crops, trees, and livestock to solve the problem of acute shortage of fuel, fodder and other goods[19]. The farmers have little opportunities to select the tree species, and therefore, they accept whatever is available on their land [20]. The various problems and constraints of agroforestry can be overcome through policy and institutional reforms[21]. Moreover, there is deficiency in the understanding of biophysical concerns correlated with productivity, water-resource sharing, soil productivity, and plant interactions in agroforestry systems, since most of the research is site-specific, observational in nature, and not process-oriented[22.] The promotion of sustainable agroforestry practices on a large scale in future is only possible through amalgamation of proactive farmer policies of government, involvement of the industries, support services from NGOs and willingness of farmers[23] for improvement in status of TOFs. Extension services are important for smooth dissemination of research results on the different aspect of agroforestry but research results on agroforestry, available in the public and private domain do not regularly reach the farmers due to lack of a proper or dedicated extension system. Also, Farmers with major land holdings will get more benefit by the agroforestry related schemes than the small and marginal farmers. So there is need to introduce special programs on agroforestry models for marginal and small farmers because 2/3rd farmers of Indian farmers are small and marginal farmers[24].

IV. CONCLUSION

The systematic pattern in tree planting needs to be improved for the region. The extension and training programmes regarding selection of species, tree planting pattern, nursery raising, quality planting material, maintenance and management of plantations and most importantly, the marketing of trees as end produce. In marketing or sale of trees, transit and felling permit to be issued by forest department is very important. The unawareness of rules and fear of administration discourages farmers for adopting agroforestry widely at large level in this region. It is now urgent need of time to adopt tree plantations in massive way in districts of Eastern Plain zone to achieve our national target of forest policy. Agroforestry adoption with suitable species of economic value will improve country's forest and tree cover to the 33%. The foresters, researches, NGOs

and tree growers & traders are needed to be coordinated on a common platform for successful implementation of agroforestry programme on massive level. Further, to enhance the efforts of farmers, sale of end products should be strengthened with the involvement of project planners and wood based industries.

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Effect of different Fungicides on Growth of *Beauveria Bassiana*

Mr. Prakash Vaghasiya[1*], Krishna Patel[2], Anjali Nair[3]
Vise Innovation Solution Enterprise Pvt. Ltd, Vadodra
*Corresponding Author

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Abstract— *Beauveria bassiana is an entomopathogenic fungus that grows naturally in soils throughout the world,which acts as a pathogen with significant host range and host specificity. Use of chemical products to protect plants and other environmental factors affects the conidial survival of beauveria bassiana fungus. This research paper mentions the compatibility of beauveria bassiana with fungicides such as Chloramphenicol, Tetracycline, Amoxicillin, Gentamicin, Mancozeb + Metalaxyl, Fluconazol. A positive result was obtained for Fluconazole, Mancozeb+Metalaxyl, Dithane (Amoxicillin + Streptomycin + Tetracycline + Chloramphenicol + Mancozeb).*

Keywords— Beauveria bassiana, Fungicides, soils, plants, environmental factors.

I. INTRODUCTION

The entomopathogenic fungi *Beauveria bassiana* functions as an effective control agent against many pests.*Beauveria bassiana* plays a key role in causing disease in arthropod populations.

Availability of adequate moisture and temperature helps *Beauveria bassiana* in acting as an important mortality factor of arthropod pests. Various commercial products are developed using this fungus due it's capability to control pests. *Beauveria bassiana* possesses all the attributes of an effective mycoinsecticide, i.e. high virulence, broad host range, flexibility of fungi to mass production and formulation and storage and product stability. Diversity and abundance of natural enemies in the soil such as *Beauveria bassiana* is affected due to man activities such as frequency and type of pesticide application .Although, abundant of bio-control agents has been introduced in the market need for chemical pesticides remains. Frequent use of chemical pesticides resulted in tremendous decline of population of entomopathogenic fungi in the soil. Furthermore, it affected their efficiency in pest regulation. Conidial survival of *Beauveria bassiana* gets affected due to environmental factors or due to use of chemicals such as fungicides and biopesticides used to control plant pests. When the fungus comes in contact with pesticides or herbicides, its efficacy gets either antagonized or synergized. Similarly, the insecticidal property of *Beauveria bassiana* also gets affected with a disruption of its natural epizootics. The effect of pesticides such as fungicides on *Beauveria bassiana* fungus was discovered after carrying out many experiments. Inhibition of *Beauveria bassiana* by many fungicides was indicated in various *in vitro* studies.

II. HISTORY OF FUNGUS BEAUVERIA BASSIANA

The entomologist BASSI Agostino of Lodi in 1985 discovered the cause of pebrine disease characterised by turning Italy's silkworms into white mummies. The symptoms of disease included appearance of cadavers covered with white powdery layer which gave rise to the name"white muscardine disease". Later, Beauverie jean described this pathogen as *Botrytis bassiana*. By twentieth century, Vuillemin (1912) claimed that *Botrytis bassiana* (Bals.-Criv) was a species that belongs to the genus Beauveria.

A new species, Cordyceps bassiana has been described from China on a carpenterworm larva, Prionoxystus robiniae (Lepidoptera: Cossidae), and is doubtless associated with *Beauveria bassiana*. The main characteristic of hyphomycetes (Deuteromycotina) is that they lack amphimixis, making the taxonomists consider only morpho-ontogenic characteristics to discriminate between species (De Kouassi 2001).

2.1 Morphology of *Beauveria Bassiana*

The fungus *Beauveria bassiana* (Bals.) Vuill acts as a pathogen for many insect orders such as: Lepidoptera, Hemiptera, Coleoptera, Hymenoptera, Homoptera, Hemiptera and Orthoptera. *Beauveria bassiana* consist of asexual spores called conidia of white to yellow colour with zig-zag transparent and septal filaments. Diameter of hyphae varies between 2.5 µm and 25 µm. Type of conidia produced by *Beauveria bassiana* depends on the environment. Spherical or oval conidia are produced in the presence of air while oval shaped blastospores are produced in anaerobic conditions.

2.2 *Beauveria Bassiana*: Mode of Action on Insects

Four steps included in the mode of action of *Beauveria bassiana* on pest insects include adhesion, germination, differentiation, penetration and dissemination. Once inside the insect, the fungus develops a hyphal body that uses haemocoel for dissemination. The insect dies after 3 days or two weeks due to infection in different muscle tissues, malpighian tubes, fatty bodies, haemocoel and mitochondria. The idea of using insect-infecting fungi for insect pest management belongs to Gilbert and Gill. Entomopathogenic fungi can be defined as a group of fungi that attack and infect the host of the insect in order to kill the insect. The major issues involved in mass production and utilization of myco-pathogens are selection of effective strains, development of cost effective methods of mass rearing, development of effective methods for storage and shipment and creation of effective formulation. So considering the importance of *Beauveria bassiana* in pest management, it felt worthwhile to research various aspects of this insect pathogen under South Gujarat conditions, where a damp atmosphere, which is favourable for multiplication of fungus, is available throughout the year. Entomopathogenic fungi play a significant role as a biocontrol agent. There are over 750 species of entomopathogenic fungi and their presence in the environment induces fungal infection in the insect population and this way they help in controlling insect pests. This fungi infect insect by a mechanism in which it initiates formation of germination tube by retaining spores on the integument surface and then by releasing enzymes such proteases, chitinases, quitobiases, Upases and lipoxygenases. Once the insect dies and lots of of the nutrients are exhausted, fungi start micelles growth and invade all the organs of the host. In the 1980s, the primary insect pathogenic studies were administered and their focus was to seek out the methods of disease management of the silkworm. These enzymes degrade the insect's cuticle and help within the process of penetration by mechanical pressure that's initiated by the appressorium, a specialized structure formed within the germinative tube. The cutworm, spodoptera litura (fabricus) (Lepidoptera:Noctuidae), may be a polyphagous sporadic pest with high mobility and reproducing capacity that has about 150 host species. In the end, the hyphae emerges outside the insect by penetrating through the cuticle and after reaching the surface, it begins spore formation when suitable environmental conditions are available .This will provide scientific information for development strategies for various insect pests. The rice weevil, Sitophilus oryzae (L.) (Coleoptera: Curculionidae) in rice grain, and the red flour beetle, Tribolium castaneum (Herbst) (Coleoptera: Tenebrionidae) in wheat grain cause quantitative and qualitative damage to grain. Insects are categorised as important pest of seeds because they attack stored seeds and damages the seed embryo resulting in reduced rate of seed germination. Qualitative damage is thanks to product alterations like loss of nutritional and aesthetic value, increased levels of rejects within the grain mass, and loss of commercial (baking) characteristics.

The entomopathogenic fungus is the most effective agent in biocontrol. It can be found in all types of soil. Different isolates of *Beauveria bassiana* act as pathogens to a wide range of insects and mites. *Beauveria bassiana* can be considered as an eco-friendly method of pest control contrary to chemical pesticides. Culturing and maintenance of *Beauveria bassiana* is cheap compared to chemical pesticides. Due to longer lifespan, insecticidal activity of *Beauveria bassiana* is faster than other entomopathogenic agents. Conidia of *Beauveria bassiana* remains in the environment for a longer time by spreading epizootic or enzootic diseases. Their affect on beneficial insects and other non-targeted organisms are limited. Due to its ability to use various mode of action and adapt to host changes, insects cannot easily develop resistance against *Beauveria bassiana*.

III. MATERIALS AND METHODS

3.1 Materials

- *Beauveria bassiana* mother culture
- Water
- SDA agar plate

- L-shaped glass spreader
- Alcohol
- Bunsen burner
- Petri dish
- Filter paper
- Measuring scale
- Incubator
- Micropipette and tips
- Microscope
- Beaker
- Conical funnel
- Flask

Antibiotics:-Chloramphenicol, Tetracycline, Amoxicillin, Gentamicin, Mancozeb+Metalaxyl, Fluconazol

3.2 Observe growth of *Beauveria bassiana* on different concentrations of fungicides:

3.2.1 For 10 ml preparation:

1. Take 9 ml of distilled water in a glass beaker.
2. Add 1 capsule of fungicide.3.For Streptomycin add 350mg in 9 ml water and for Mancozeb + Metalaxyl 250mg, Dithane (Mancozeb) 350mg add in 9 ml water.
3. Dissolve properly with the help of glass rod.
4. Antibiotic solution is poured into a conical funnel fitted with a filter paper and collects antibiotic solution (filtrate) into a flask.
5. Make a fungal solution 10 ml.

3.2.2 10 ml combination of different fungicidal dose:

1. Take 1 ml of fungicide which is prepared by the above given method.
2. Take 1 ml of different fungicides and mix up in one test tube.

Different combinations of fungicides:

C_1 = Amoxicillin + Streptomycin + Tetracycline + Chloramphenicol

C_2 = Amoxicillin + Streptomycin + Tetracycline + Chloramphenicol + Mancozeb (Dithen)

$C_3 = C_2$ + Gentamicin

$C_4 = C_3$ + Fluconazole

$C_5 = C_1$ + (Mancozeb +Metalaxyl)

3.2.3 For 100 ml preparation:

1. Take 90 ml of distilled water in a glass beaker.
2. Add 1 capsule of fungicides.
3. For Streptomycin, add 350 mg in 100 ml water and for Mancozeb + Metalaxyl 250 mg, Dithen (Mancozeb) 350 mg add in 100 ml water.
4. Dissolve properly with the help of a glass rod.

5. Fungal solution is poured into a conical funnel fitted with a filter paper and collect fungal solution (filtrate) into a flask.
6. Make up fungal solution 100 ml.

3.2.4 Disc Diffusion Method:

1. First of all, make a suspension using fungicides.
2. Take a loop of full mycelia growth of the fungus to the pure culture plate of Beauveria bassiana.
3. Dissolve it in 10 ml of sterile distilled water.
4. Pipette out 0.1 ml from the desired dilution series onto the center of the surface of an SDA agar plate.
5. Dip the L-shaped glass spreader into alcohol.
6. Flame the glass spreader over a Bunsen burner.
7. Spread the sample evenly over the spreader of agar using the sterile glass spreader, carefully rotating the Petri dish underneath at the same time.
8. The disc diffusion assay was performed in a sterilized petri plate of 10 cm diameter.
9. Different dilutions of the fungicides were impregnated on the sterilized discs (5 mm in diameter) of whatman filter paper number 1.
10. The discs were placed on the surface of the SDA agar plate which was already inoculated with *Beauveria bassiana* culture suspension.
11. The plates were inoculated at 25℃ and examined after 48 hour for zones of inhibition, if any, around the disc.
12. The diameter of the zone of inhibition was measured with the help of a scale.

IV. RESULT AND DISCUSSION

Among the fungicides used, a maximum zone of inhibition was observed in the case of fluconazole covering an area of 0.9mm. On the other hand, the zone of inhibition recorded in case of gentamicin was the least with an area covering 0.2 mm. In case of mancozeb+metalaxyl, dithane and streptomycin the zone of inhibition recorded was 0.8, 0.7 and 0.6 respectively, which can be considered moderate. On the contrary to this, amoxicillin and streptomycin showed minimum inhibition to beauveria fungi in an area of 0.3 and 0.2 respectively. Fungicides such as fluconazole which showed maximum inhibition to beauveria when applied in the soil, restricts the growth of natural biocontrol agents like beauveria in the soil. Whereas, gentamicin application has minimal effect on the lives of *Beauveria bassiana* hence can be used in the soil without killing the beneficial organisms present in the soil.

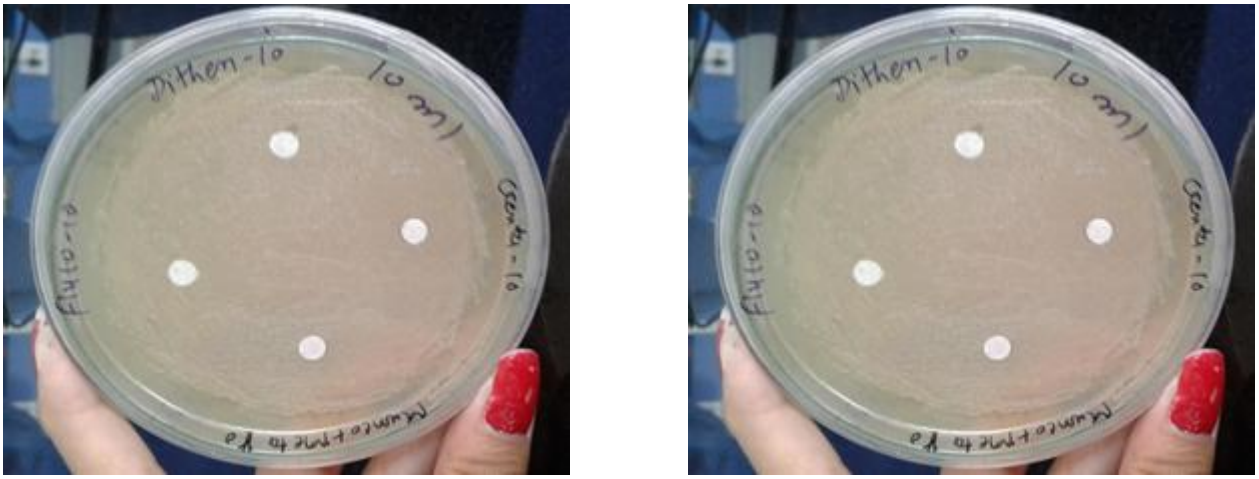

FIGURE 1: [10ml : Fluconazole, Dithane, Manco+Metalexyle, Amoxicillin, Chloramphenicol, Gentamicin, Tetracycline]

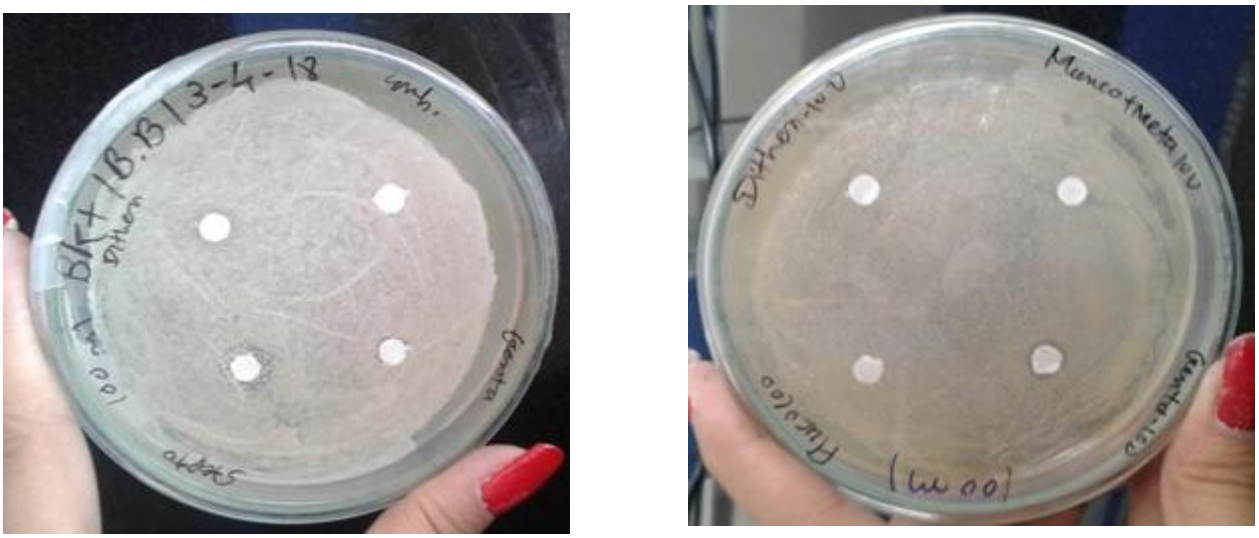

FIGURE 2: [100 ml : Dithen, Streptomycin, Fluconazole, Gentamicin, mancozeb + Metalaxyl, Amoxicillin]

V. CONCLUSION

The Use of biological control agents such as entomopathogenic fungi (EPS) can be used as a component of integrated pest management (IPM) of many pests. Several fungal species such as *Beauveria bassiana* are being used as biocontrol agents for a number of crops, livestock and human nuisance pests. Hence it is very important to ensure availability of these bioagents in the soil by avoiding the use of fungicides and other pesticides that inhibit their growth. In this research paper we have discussed how affect of fungicides on *Beauveria bassiana* varies depending on the type of fungicide and the result helped in determining which fungicides should be used to ensure the survival and growth of beauveria bassiana in the soil. Instead of using fungicides such as fluconazole and mancozeb+metalaxyl, which shows high rate of inhibition of growth of *Beauveria bassiana*, fungicides such as gentamicin that shows minimum rate of inhibition should be used. Fungicides that inhibit growth of *Beauveria bassiana* such as fluconazole and mancozeb+metalaxyl, when applied in the soil, reduces the population of beneficial *Beauveria bassiana* that are naturally available in the soil and results in increased dependency on chemical pesticides for controlling pests. Use of fungicides like gentamicin helps in conserving the population of *Beauveria bassiana* in the soil, which acts as a natural biocontrol agent.

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Eco-friendly application of vermiwash obtained from different types of waste with neem seed kernel extract against papaya mealybug, *Paracoccus marginatus* Williams and Granara de Willink

K. Sharjana[1*], G. Mikunthan[2], H.N.P. Wijayagunasekara[3]

[1,3]Postgraduate Institute of Agriculture, University of Peradeniya, Sri Lanka
[2]Department of Agricultural Biology, Faculty of Agriculture, University of Jaffna, Sri Lanka
*Corresponding Author

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Abstract— *Excessive agro-chemical usage has created a serious threat to the environment and human health. On the other hand, inappropriate bio solid waste management has given rise to social and environmental issues. Vermicomposting can be one of the solutions for both problems. Vermiwash is a product from vermicomposting which is generally used as a foliar fertiliser. Besides, it can also be used as a mild biopesticide in organic farming. In this study, three different substrates (cow dung, goat manure and vegetable waste) were used to produce vermiwash. Neem seed kernel (NSK) extract was combined with the vermiwash obtained from the different substrates to treat papaya mealybug (Paracoccus marginatus) and its predators on Carica papaya. 40% vermiwash and 10% NSK extract were used for the field study. The foliar application of vermiwash (cow dung) + NSK extract (1:1), vermiwash (goat manure) + NSK extract (1:1), vermiwash (vegetable waste) + NSK extract (1:1), vermiwash (cow dung), vermiwash (goat manure), vermiwash (vegetable waste) and control treatment resulted 75.72%, 67.19%, 57.62%, 45.00 %, 40.90%, 33.78% and 00.00% of papaya mealybug population reduction respectively. The combination of vermiwash obtained from cow dung and neem seed kernel extract (1:1) showed a higher performance in suppressing papaya mealybug population in field condition. There was no remarkable population reduction of the mealy bug predators after the application.*

Keywords— Vermiwash, Paracoccus marginatus, Natural predators, Neem seed kernel extract, Organic farming.

I. INTRODUCTION

The concern of organic farming and sustainable agriculture has increased in recent years. Unrestrained applications of fertilisers and pesticides in agriculture have caused adverse effect on the environment [1]. Meanwhile the rate of solid waste generation is escalating with population increase and industrialisation [2]. Improper management of bio solid waste cause serious problems in the society [3]. Vermicomposting is one of the environmental friendly methods in converting various bio wastes through earthworms into vermicompost and vermiwash [4]. These eco-friendly products can be an alternative to agro-chemicals. Vermiwash is a brownish-red liquid extract collected after the passage of water through a column of vermiculture. It is a collection of coelomic fluid and excretory products of the earthworms. The liquid fertiliser vermiwash helps to enhance crop productivity. Besides, it is effective against pests and diseases [5]. Vermiwash is rich in several nutrients, vitamins and plant growth regulators [6]. It also comprises insecticidal and antifungal bioactive compounds which suppress pest and diseases [7]. Earthworms express coelomic fluid when under severe stress condition. The coelomic fluid of the earthworm is secreted through dorsal pores in the form of mucus as a response of defense mechanism. The biological activity of the earthworm depends on the type of waste material provided as the feed for vermicomposting. The performance of *Eisenia foetida* varies in different types of waste used for vermicuture [8]. A number of studies have been undertaken on vermiwash as a liquid fertiliser in many crops. However, the study on application of vermiwash obtained from different types of waste in pest management is scarce.

There are various number of plant based pesticides used to manage the pests in organic farming. Neem (*Azadirachta indica A. Juss*) has remarkable insecticidal properties [9]. Azadirachtin is a component of neem which is an effective plant based pesticide and also has antifeedant and toxic effects on insects [10, 11]. In this study neem seed kernel extract was selected as a plant based pesticide to combine with vermiwash to manage soft body insects in papaya cultivation.

Papaya mealybug (*Paracoccus marginatus* Williams and Granara de Willink) of order Hemiptera, family Pseudococcidae is a severe pest of *Carica papaya* [12]. It is an invasive pest to Sri Lanka; it was first reported in Colombo and Gampaha districts in July 2008 [13]. It is a pest in fruit and vegetable crops and ornamental plants. It has a very wide host range extending up to 22 families of plants in Asia [14]. The insect feeds on leaves, stems and fruits and sucks the sap causing stunting of the plants, chlorosis, early fruit drop and death. Sooty mould is formed by the honeydew secreted by the insects while feeding [15]. There were many natural enemies of papaya mealybug recorded in the field. Insect like green lacewing (*Chrysoperla carnea* Stephens - Neuroptera: Chrysopidae) and coccinellid beetle (*Anegleis cardoni* Weise) and a spider species (*Phintella vittata* - Arachnida: Araneae: Salticidae) were recorded to predate on papaya mealybugs [16, 17]. Frequent and excess use of chemical insecticides results in depletion of natural enemies [18]. Thus, there is a need to use alternative environmental friendly insecticides to sustain the management. The objective of the study is to test the effect of different types of vermiwash and neem seed kernel extract on papaya mealybugs and its predators on *Carica papaya* as an environmental friendly solution.

II. METHODOLOGY

Vermiwash and neem seed kernel extract were prepared at the Department of Agricultural Biology, Faculty of Agriculture, University of Jaffna, Ariviyal nagar, Kilinochchi, Sri Lanka. Different types of vermiwash were obtained by using *Eisienia foetida* in the vermicompost unit.

2.1 Collection of vermiwash

Three identical 250L one side opened empty barrels were taken for the preparation of vermicompost. A hole was made at the lower end of each barrel to accommodate a vertical limb of 'T' jointed tube in a way that one inch of the tube was inside the barrel. A tap was attached to the outer end of the tube in order to collect the vermiwash. 25cm of broken bricks were placed at the bottom of the barrel as a filter unit. Above the brick layer, a 30cm of loamy soil was placed. On top of this, a 30cm layer of cow dung in the first barrel, goat manure in the second and vegetable wastes in the third were added separately. The substrates were moistened with water. *Eisienia foetida* earthworms of 0.5kg were released in the barrels. The vermicompost barrels were covered with muslin cloth for protection. Freshwater was sprinkled daily to maintain the moisture (80%). The mixture was manually turned up once a week for 3 weeks. After 28 days, the three different types of vermiwash from each barrel were collected and labelled as vermiwash (cow dung), vermiwash (goat manure) and vermiwash (vegetable waste).

2.2 Preparation of neem seed kernel extract

200g of cleaned, shade dried kernels of neem were ground properly, soaked for 24 hours in 1L of distilled water and squeezed through muslin cloth to obtain the extract. The volume of the extract was then made up to 4L by adding 3L of distilled water. A concentration of 10% of this extract was used for the treatments. A detergent powder (0.1%) was added as a spreading agent just prior to the treatment [19].

2.3 Field studies

A field study was conducted in a farmer field in Urumpirai, in the Jaffna district in June 2017 to evaluate the efficacy of selected treatments in completely randomized block design. Red lady variety *Carica papaya* trees of the age of 15 months were selected for the study. The treatments were applied when the crop reached 25-50% of leaves/fruits damage (Table 1). The total number of papaya mealybugs in $16cm^2$ per fruit was counted using hand lens. The initial count of the papaya mealybugs was recorded a day before the first treatment. The respective treatments were applied using hand sprayers in a 14 day interval. Each treatment was replicated five times with each replicate being an individual plant. Treatments were evaluated 7, 14, 21 and 28 days after the initial spray. Additionally, the number of predators was recorded for each treatment.

2.4 Statistical analysis

Pest and predator population reduction levels at all treatments were subjected to analysis of variance (ANOVA) and the means were separated by Duncan's Multiple Range Test (DMRT) using SAS. Percentage of reduction was calculated according to Henderson-Tilton formula.

TABLE 1
DETAILS OF TREATMENTS USED AGAINST PAPAYA MEALYBUG

Treatment Number	Treatment
T1	40% Vermiwash (goat manure)
T2	40% Vermiwash (cow dung)
T3	40% Vermiwash (vegetable waste)
T4	40% Vermiwash (goat manure) + 10% NSK extract (1:1)
T5	40% Vermiwash (cow dung) + 10% NSK extract (1:1)
T6	40% Vermiwash (vegetable waste) + 10% NSK extract (1:1)
T7	Control

NSK – Neem seed kernel

III. RESULTS AND DISCUSSION

In the field experiment all treatments showed a gradual reduction in papaya mealybug population compared to the control (Table 2).

TABLE 2
THE MEAN NUMBER OF PAPAYA MEALYBUGS AND PERCENTAGE OF REDUCTION

Treatment Number	Treatments	Mean ± SE of papaya mealybug					Population reduction % in week 4
			1st application		2nd application		
		PTC	7 DAT	14 DAT	7 DAT	14 DAT	
T1	40% Vermiwash (goat manure)	32.00	31.2 ± 1.3^{b}	30.40 ± 0.8^{b}	28.20 ± 0.9^{c}	27.00 ± 0.8^{c}	40.90
T2	40% Vermiwash (cow dung)	32.60	31.00 ± 1.5^{b}	29.80 ± 1.5^{b}	27.20 ± 1.1^{c}	25.60 ± 0.8^{d}	45.00
T3	40% Vermiwash (vegetable waste)	33.00	33.00 ± 0.8^{b}	32.60 ± 1.7^{b}	31.00 ± 0.8^{b}	31.20 ± 0.8^{b}	33.78
T4	40% Vermiwash (goat manure) + 10% NSK extract (1:1)	31.60	24.00 ± 1.3^{cd}	22.00 ± 1.7^{c}	18.80 ± 1.5^{e}	14.80 ± 1.2^{g}	67.19
T5	40% Vermiwash (cow dung) + 10% NSK extract (1:1)	30.00	21.60 ± 0.8^{de}	19.00 ± 1.5^{c}	14.60 ± 1.2^{e}	10.40 ± 0.8^{f}	75.72
T6	40% Vermiwash (vegetable waste) + 10% NSK extract (1:1)	31.40	25.60 ± 1.6^{bc}	24.80 ± 2.4^{c}	22.00 ± 2.4^{d}	19.00 ± 2.2^{e}	57.62
T7	Control	31.80	38.40 ± 1.8^{a}	39.40 ± 1.6^{a}	40.20 ± 0.9^{a}	45.40 ± 1.0^{a}	-

Means having same letters in a column indicate that the values are not significantly different at 0.05 α by DMRT, SE – standard error, NSK- neem seed kernel, PTC- pre-treatment count, DAT- day after treatment

Applications combined with neem seed kernel extract showed a higher pest population reduction level than the sole applications of vermiwash. Neem seed kernel extract contains insecticidal compound called Azadirachtin which has repellent and antifeedant effects against insect pest [10, 11]. In the 4th week, the mixed application of 40% vermiwash (cow dung) + 10% NSK extract (1:1) showed a higher pest reduction of 75.72% followed by the combined applications of 40% vermiwash (goat manure) + 10% NSK extract (1:1) with 67.19% and 40% vermiwash (vegetable waste) + 10% NSK extract (1:1) with 57.62%. A similar study on insect pest management reported that, combined application of vermiwash with plant extracts suppressed the infestation of thrips and mites and improved productivity of the crop [20]. Vermiwash contains numerous enzymes, vitamins, macro and micro nutrients, hormones, insecticidal and antimicrobial properties which support plant health and protection [6, 7]. Tracy in 1951 reported the activity of chitinase in the posterior part of the intestine of earthworm's mid gut [21]. Chitinase in earthworms not only supports digestive function but also engages in defense mechanism against chitin containing organisms [22]. Chitinase present in the vermicast repels insects; the enzyme degrades the chitin in the arthropods exoskeleton [23, 24, 25]. However, the mechanism of vermiwash in reduction of population

density of mealybugs was less clear. In other related studies on soft body arthropods, applications of vermiwash have reduced the pest population of sucking insects [26, 27, 28].

Sole applications of 40% vermiwash obtained from cow dung, goat manure and vegetable waste resulted 45.00%, 40.90% and 33.78% of pest suppression respectively. There was a significant difference in mealybug population reduction between vermiwash prepared by using cow dung and goat manure. This may be due to the performance of the earthworms in different animal wastes. *Eisienia foetida* biomass, reproduction performance, cocoon production per worm and growth rate were reported high in cattle manure than goat manure [8, 29]. Vermiwash obtained from the vegetable substrate showed the least efficacy in insect suppression level. It may be due to the poor growth of the earthworms in the vegetable waste. Growth and reproduction of the earthworms depend on the biochemical quality of the substrates provided as feed [30]. The biochemical quality of the vermiwash varies based on the types of waste used in vermicomposting [31].

TABLE 3
POPULATION REDUCTION OF PREDATORS OF MEALYBUG BY TREATMENTS

Treatment Number	Treatments	Reduction of population %					
		Coccinellid		Green lacewing		Spider	
		14 DAT	28 DAT	14 DAT	28 DAT	14 DAT	28 DAT
T1	40% Vermiwash (goat manure)	-40.00*	-20.00*	-68.00*	-40.00*	-33.33*	-25.00*
T2	40% Vermiwash (cow dung)	-16.67*	00.00	-40.00*	00.00	-77.78*	-33.33*
T3	40% Vermiwash (vegetable waste)	-28.33*	-10.00*	-54.00*	-28.33*	-33.33*	-20.00*
T4	40% Vermiwash (goat manure) + 10% NSK extract (1:1)	-40.00*	-20.00*	-68.00*	-40.00*	-33.33*	-25.00*
T5	40% Vermiwash (cow dung) + 10% NSK extract (1:1)	-16.67*	00.00	-16.67*	00.78	-66.67*	-25.00*
T6	40% Vermiwash (vegetable waste) + 10% NSK extract (1:1)	-40.00*	-20.00*	-68.00*	-40.00*	-55.56*	-33.33*
T7	Control	-	-	-	-	-	-

NSK- neem seed kernel, DAT- day after treatment,* negative sign (-) means no reduction in population

The data collected on predators revealed that there were no reduction in coccinellid beetle (*Anegleis cardoni*) and spider (*Phintella vittata)* population in the field after the application (Table 3). However, 40% Vermiwash (cow dung) + 10% NSK extract showed a slight population reduction of 0.78% on soft body insect green lacewing (*Chrysoperla carnea* Stephens). Overall, the sprays showed less harm to the mealybug predators in the habitat.

IV. CONCLUSION

The efficacy of vermiwash mixed with neem seed kernel extract against papaya mealybugs was higher than the treatments solely with vermiwash. Since vermiwash is a mild bio pesticide it can be combined with neem seed kernel extract in pest management. Mixed foliar application of 40% vermiwash (cow dung) and 10% neem seed kernel extract (1:1) in an interval of 2 weeks curtailed the population build up of papaya mealybugs. This cost effective combination of application was identified as a remedy for pest problem on papaya crops in organic farming and home gardening. Vermiwash obtained from cow dung showed a higher pest population reduction level than the vermiwash obtained from goat manure and vegetable waste. The type of waste used for vermiwash production influenced the efficacy level of pest suppression. The eco-friendly treatments showed negligible effect on predators of papaya mealybugs.

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