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TABLE OF CONTENTS

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Non-Timber Forest Products: Constraints and Prospects in Rainforest Communities in Nguti Sub-division, South West Region, Cameroon

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Abstract:
This study assessed the constraints and prospects of production and marketing of non-timber forest products (NTFPs) by farmers. This study aimed to identify the main constraints and prospects of production and marketing of major NTFPs within the Nguti Sub-Division. Three villages were randomly selected in the Subdivision. Thirty (30) respondents were sampled in Ediengoh, Ofrikpabi and thirty-two (32) from Ekenge making a total number of 92 respondents. Descriptive statistics was also used to calculate frequencies, percentages and chi-square was used to test for the level of association between variables at p=0.05. Forty six percent (46.7%) were men while 53.3% were women. Forty two percent (42.4%) had farming experience for 6-10 years. The main NTFP that was produced and marketed was Irvingia wombulu at (31.5%) and the least was Gnetum africana which stood at (3.3%). The major marketing problems challenging the farmers of the NTFPs was significant (X2cal=86.95, X2tab=7.815) with lack of storage facilities at the top followed by inadequate market information and low purchasing power of buyers. The major constraint of production noticed was duration taken for vegetative growth (X2cal=82,26, X2tab =7.815), followed by inadequate access to credits and inadequate extension support/ advisory services. There is therefore urgent need for producers to embark on simple processing and packaging technologies to reduce wastage and value add to the products. This study recommends domestication of fast-growing species and government to improve rural road networks for produces taken to markets.

Keywords: NTFPs, production, constraint, market, Rainforest communities, Nguti Sub-division

INTRODUCTION

Globally, more than one-fourth of the world's population rely on the forest for food and livelihood, 60% of whom are indigenous and tribal communities (FAO, 2015). These include products from plants and trees (e.g., medicinal plants, herbs, resins, fruits, nuts, etc.), as well as animals (e.g., honey, bush meat, fish). As one of the major sources of livelihood for tribal communities in many of the developing countries, NTFPs act as community safety nets where agriculture is unable to provide a sustainable income. Further, NTFPs are also used for cultural and recreational purposes, and offer various opportunities, including cultural maintenance and revival, forest biodiversity support, and rural economic development (Cocksedge, 2006).

Despite the increasing knowledge, the NTFPs sector is still strongly underutilised. The main constraints of the NTFP sector are "scarcity of raw material (in terms of both quantity and

seasonal availability), low market transparency, inadequate business and marketing skills, small market size and high production and transport costs" (Maso et al., 2011). Further challenges include market inefficiencies for products that are produced in low quantities, especially when both the quantity and quality of the products can vary due to changes in the weather and other production conditions.

Although NTFPs are an important source of subsistence and cash income, there is growing concern regarding the fact that overharvesting fuelled by an increasing population and market demand is accelerating stock depletion (Arnold & Perez, 2001; Belcher et al., 2005). Domestication is also crucial for improving genetic quality in order to realize higher yields, extended periods of production, and the development of tolerance to variable temperature and soil conditions (Leaky &Izac, 1996).

In Cameroon, as in most developing countries with forest cover, Non-Timber Forest Products ensure the maintenance of food security for many rural households (Guedje et al., 1998). Rural communities get most of the craft material, food, medicine and spirituality (Abanda, 2013). It is in this perspective that this study seeks to assess the constraints and prospects in the production and marketing of Non-Timber Forest Products in the Nguti Sub-division, South West Region of Cameroon.

MATERIALS AND METHODS

Description of Study Site

Nguti Sub-division is found in KupeMuanenguba Division of the South West Region of Cameroon. It is 94 km from the town of Kumba and has an altitude of about 400 m above sea level, with a surface area of 1500 km² (Nguti Council, 2016). The subdivision shares common boundaries to the North with Tinto Sub division, to the South with Konye Sub division, to the South-East with Bangem and Melong, to the East with Santchou, Dschang and Fontem and to the West with Eyumojock and Toko (Figure 1). Topographically, the land is generally flat and raised 400 m above sea level with gentle and steep hills dotted within the thick humid forest in the municipality. It is host to two forest reserves including BayangMbo and the Nguti Council Forest with timber resources, wildlife and medicinal plants. Its coordinates are 5°15'0N and 9° 30'0E, Nguti Municipality is within the equatorial rain forest with a climate which is characterized by two distinct seasons; the rainy and the dry seasons. The dry season runs from October to March and is characterized by elevated temperatures (30°C-32°C). The rainy season begins from March to September or October. Peak periods are during the months of July and August. There are 54 villages and nine clans which are geographically separated by the MbayangMbo Wildlife Sanctuary (Nguti Council, 2016).

According to the monographic Study Nguti Council, August (2009), the main economic activities of communities in Nguti are farming (70%), hunting (20%), fishing (5%) and the collection of non-timber forest products (5%). The main local markets are ElumbaMbo, Mbetta, Nguti and Manyemen, where farming produce (cocoa, coffee, palm oil, vegetables) and other food items (bush meat, salt, fresh fish) are sold. This illustrates how reliant local communities are on forest land and resources. When access to these is compromised, so are the communities' livelihoods and wellbeing.

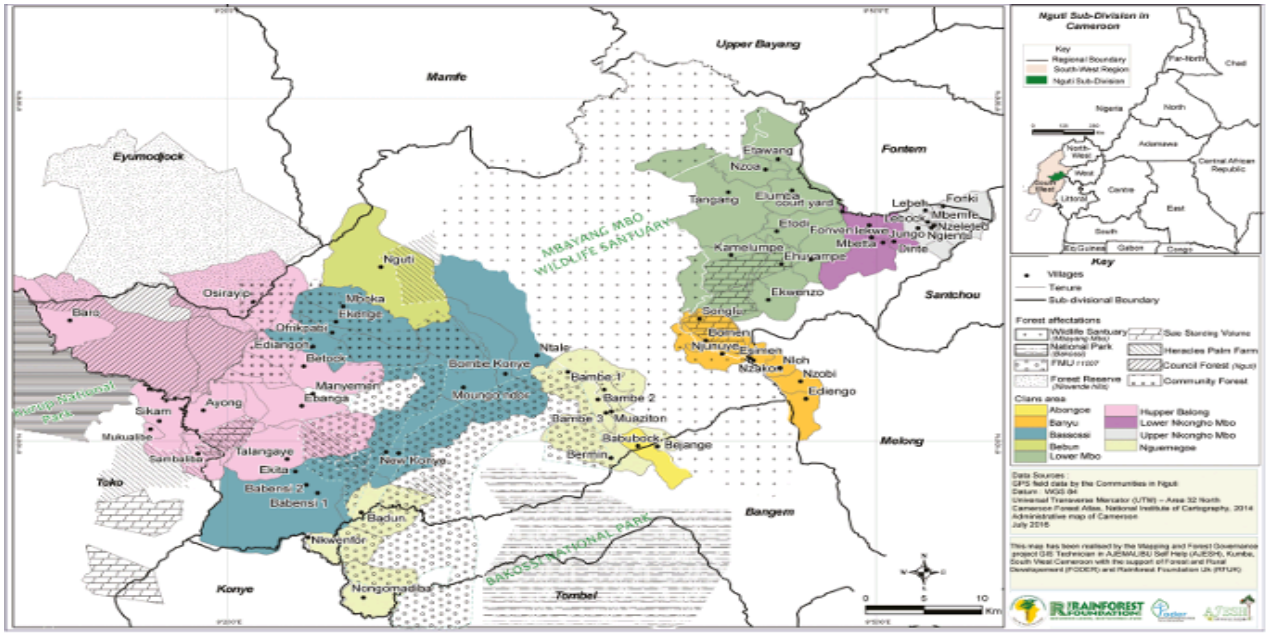

Figure 1: Map of the study sites, source: Nguti council, 2010

Population of the Study

This study was conducted in three villages in the Nguti subdivision. These villages include Ediengoh, Ofrikpabi and Ekenge. The Ediengoh has a total population of 103, Ofrikpabi 100 and Ekenge 401, giving a population size of 604 inhabitants (Nguti-Council, September 2016). The total population of the study was 120, consideration was taken for household which were not involved in the production and marketing of NTFPs as well as households which have not been involved in the activities for more than five years. The sample size was 92 respondents, 30, 30, and 32 respondents were involved in the production, gathering and marketing of NTFPs were selected randomly from each village (Ediengoh, Ofrikpabi and Ekenge) respectively. The sample size of the study was determined with the aid of the Krejcei and Morgan table, where 92 is a representative sample of the studied population.

Data Collection

The field work was carried out from January to May 2022 and questionnaires were administered to both male and female respondents involved in the production and marketing of NTFPs in Nguti Sub-division. Basically, primary and secondary methods of data collection were used;

Primary Data Collection:

Primary data was collected by using well-structured questionnaires with open and closed ended questions made up of three sections. Section A comprise of the socio-economic characteristics of the respondents for example gender, age of respondents in years and level of education, section B the NTFPs that are produced and marketed such as do you produce NTFPs?, which are the NTFPs produced? , section C dwell on the opportunities of production and marketing of NTFPs for example increase growth of the community, increase in income and section D consist of the constraints and prospects involved in the production and marketing of NTFPs for example lack of knowledge to identify and harvest certain NTFPs, lower purchasing powers of the market agents, NTFPs should be domesticated and storage facilities created and field observation. Discussions with key informants were also used to collect information.

Secondary Data:

The secondary data were collected from scientific publications, the university library, electronic documents (internet) and documents from establishments from Nguti council and Divisional Delegation of Agriculture and Rural Development.

DATA ANALYSIS

The quantitative data obtained from the household survey was coded and analyse using IBM Statistical Package for Social Science (SPSS) version 16.0. Descriptive statistics was also used to calculate frequencies, percentages and chi-square was used to test for the level of association at p= 95% and significance.

RESULTS

Socio-Demographic Characteristics of Farmers in Nguti Sub-Division

The result on socio-demographic characteristics of respondents in the study area is shown in Table 1 below. The NTFPs producers and marketers sex ratio showed that 46.7% were men while 53.3% were women.

43.5% of the respondents who were involved in production and marketing of NTFPs were below the age range of 18-40 years and 16.5% were above the age range of 60 years while 40.2% of the respondents were between 41-60years.

Table 1 on educational level showed that 33.7% of the respondents attained primary school; 41.3% attained secondary education, while 14.1% did not attained any formal education but only 10. 9% attained university education.

Results on household size on table 1 indicated that 45.7% of the respondents have a household size of 1-5, 38. 0% has a household size of 6-10 and 16.3% have 11-15 persons.

Furthermore, on table 1 the results showed that 59.8% of the respondents' source for labour comes from family labour, 26.1% comes from hired labour and 14.1% comes from njangi.

Also, it was noticed in table 1 that majority (42,4%) of the respondents involved in production and marketing of NTFPs had farming experience for 6-10 years 31.5% 11-15 years, 21.7% had experience for more than 16 years and 4.3% of the respondents had farming experience for less than 5 years.

Regarding the monthly income from the sales of NTFPs, as shown on table 1, 29.3% of the respondents earn < 20.000frs, 43.5% earn 20.000-50.000frs, 23.9% earn 60.000-100.000frs and 3.3% earn >100.000frs.

Also, based on farm sizes as observed on table 1, 29.3% had 1-5ha, 27.2% had 6-10ha, 35.9% had 11-15ha and 7.6% had more than 16 ha. Furthermore, regarding the primary occupation of the respondents as reported in table 1, 95.7% were farmers, 2,2% were civil servants and 2,2% were business men.

Table 1: Socio-demographic characteristics of farmers

Variables	Frequency	Percentage
Male	43	46,7
Female	49	53,3
Total	**92**	**100,0**
Age group		
18-40	40	43,5
41-60	37	40,2
>60	15	16,3
Total	**92**	**100,0**
Level of education		
No formal education	13	14,1
Primary education	38	33,7
Secondary education	31	41,3
University education	10	10,9
Total	**92**	**100,0**
Household size		
1-5	42	45,7
6-10	35	38,0
11-15	15	16,3
Total	**92**	**100,0**
Source of labour		
Family labour	55	59,8
Hired labour	24	26,1
Njangi	13	14,1
Total	**92**	**100,0**
Farmingexperience		
<5 years	4	4,3
6-10 years	39	42,4
11-15 years	29	31,5
>16 years	20	21,7
Total	**92**	**100,0**
Farm size		
1-5 ha	27	29,3
6-10 ha	25	27,2
11-15 ha	33	35,9
>16 ha	7	7,6
Total	**92**	**100,0**
Monthlyincome		
<20.000frs	27	29,3
20.000-50.000frs	40	43,5
60.000-100.000frs	22	23,9
>100.000frs	3	3,3

Total	**92**	**100,0**
Primary occupation		
Farming	88	95,7
Civil servant	2	2,2
Business	2	2,2
Total	**92**	**100,0**

The Major NTFPs Produced and Marketed in Nguti Sub-Division

Based on table 2 below, 21.7% of the respondents are involved in the production and marketing of rainy season bush mango, the highest NTFP that was produced and marketed was in the dry season bush mango at 31.5%, 19.6% of njangsa, 12.0% of the respondents produced and marketed bitter cola, 7.6% produce country onion, whereas the least NTFP that were being produced and marketed in the area of study were eru which stood at 3.3% followed by bush pepper at 4.3% (Table 2).

As shown on table 2 the parts used for*Recinodendron heudelotii, Garcinla kola, Afrostyrax lepidophyllus*are seeds, for *Irvingia gabonesis, Irvingia wombulu* are *kernels, and Piper guineeses* the leaves and seeds.

Table 2: Major NTFPs collected and marketed in Nguti Subdivision

s/n	Scientific name	Common name	Part used	% Produced	% Marketed
1	Irvingiagabonesis	Rainy season bush mango	Kernel	21.7	21.7
2	Irvingia. wombolu	Dry season bush mango	Kernel	31.5	31.5
3	Recinodendron heudelotii	Njangsa	Seed	19.6	19.6
4	Garcinla kola	Bitter cola	Seed	12.0	12.0
5	Afrostyrax lepidophyllus	Country onion	Seed, bark	7.6	7.6
6	Gnetum africanum	Eru	Leaves	3.3	3.3
7	Piper guineeses	Bush pepper	Leaves, seed	4.3	4.3

Opportunities of Production and Marketing of NTFPs in the Nguti Subdivision

As shown in table 3 below, 59.8% strongly agreed that the production and marketing of NTFPs has led to an increase in income, 35.9% agreed it has led to an increase in income, 3.3% disagreed that the production and marketing of NTFPs has not led to an increased in their income and 1.1% strongly disagreed (X^{2cal}=87.30, x^{2tab}=7.815).

With respect to seasonal employment as an opportunity for the production and marketing of NTFPs, 54.3% strongly agreed that NTFP business has led to seasonal employment, 35.9% agreed the production and marketing of NTFPs has led to seasonal employment, 7.6% strongly disagreed and 2.2% disagreed (X^{2cal}=66.34, x^{2tab}=7.815).

Based on the table 3 below, 55.4% of the respondents strongly agreed the production and marketing of NTFPs is a great opportunity because the can be stored and sold later, 42.4% agreed and 2.2% strongly disagreed which showed a significant difference (X^{2cal}=42,54, x^{2tab}=5.991).

In addition to the opportunities mentioned above, 62.0% respondents strongly agreed that the production and marketing of NTFPs is an opportunity because these products are not easily

perishable, 34.8% agreed they are not easily perishable whereas 3.3% disagreed (X^{2cal}=47,63, x^{2tab}=5.991).

Also, as seen on the table below, 67.4% of the respondents strongly agreed that there is a high demand for NTFPs, 30.4% agreed that there is a demand for NTFPs and 2.2% strongly disagreed that there no increase in the demand for these products (X^{2cal}=47,63, x^{2tab}=5.991).

Table 3: Opportunities of production and marketing of NTFPs

Variables			**X^{2cal}**	**X^{2tab}=value**
increase in income	**Frequency**	**Percent**		
Strongly agreed	55	59.8		
Agreed	33	35.9		
Strongly disagreed	1	1.1	87.30	7.815 ***
Disagreed	3	3.3		
Total	**92**	**100.0**		
Seasonal employment				
Strongly agreed	50	54.3		
Agreed	33	35.9		
Strongly disagreed	7	7.6	66.34	7.815 ***
Disagreed	2	2.2		
Total	**92**	**100.0**		
Can be stored and sold later	**Frequency**	**Percent**		
Strong agreed	51	55.4		
Agreed	39	42.4	42,54	5.991 ***
Strongly disagreed	2	2.2		
Total	**92**	**100.0**		
Not perishable	**Frequency**	**Percent**		
Strongly agreed	57	62.0		
Agreed	32	34.8	47,63	5.991 ***
Strongly disagreed	3	3.3		
Total	**92**	**100.0**		
High demand	**Frequency**	**Percent**		
Strongly greed	62	67.4		
Agreed	28	30.4	59,04	5.991***
Strongly disagreed	2	2.2		
Total	**92**	**100.0**		

(* at p<0.05, ** significant at p<0.01: *** significant < 0.001, ns not significant)

Constraints and Prospects of Production and Marketing of NTFPs

Constraints of production and marketing of NTFPs:

Constraints of production of NTFPs:

As seen on table 4 below, 48.9% strongly agreed that unsustainable harvesting of NTFPs has greatly affected the production of these products, 42.4% agreed it has led to a decrease in production, 8.7% strongly disagreed that unsustainable harvesting of NTFPs has not affected production ($X^{2\ cal}$=25,71, x^{2tab}=5.991) showed a significant difference (Table 4).

With respect to lack of access to credits, 43.8% strongly agreed that it affected production, 48.3% agreed it affected production, 5.6% strongly disagreed that lack of access to credit has not affected production of NTFPs and 2.2% disagreed (X^{2cal}=63,76, x^{2tab}=7.815). Again, based on table 4 below, 48.9% of the respondents strongly agreed that continues deforestion has affected production of NTFPs , 39.1% agreed it had a negative effects on production and 6.5% strongly disagreed that continuous deforestation has not affected production and 5.4% disagreed (X^{2cal}=55,04, $x^{2\ tab}$=7.815). As noticed on the table 4 below, 50.0% respondents strongly agreed that poor rate of seed germination affects production of NTFPs , 41.3% agreed similar whereas, 8.7% strongly disagreed that poor seed germination did not affects production (X^{2cal}=26,17, x^{2tab}=5.991). Next, 56.6% of the respondents strongly agreed that NTFPs take longer periods to grow before it start producing fruits which therefore affects production, 39.1% agreed similar 2.2% strongly disagreed and 2.2% disagreed it does not affect production (X^{2cal}=82,26, x^{2tab}=7.815). Furthermore, 50.0% strongly agreed in adequate extension support/advisory services has greatly affected the production of NTFPs in the community, 30.0 agreed, 6.5% strongly disagreed that inadequate extension services has not affected production and 5.4% disagreed (X^{2cal}=55,91, $^{x2\ tab}$=7.815).

Table 4: Shows constraints in NTFPs production

Variables			**X ^{2}cal**	**x^2 tab**
Unsustainable harvesting of ntfps	**Frequency**	**Percent**		
Strongly agreed	45	48.9		
Agreed	39	42.4	25,71	5.99***
Strongly disagreed	8	8.7		
Total	**92**	**100.0**		
Lack access to credits	**Frequency**	**Percent**		
Strongly agreed	39	43.8		
Agreed	43	48.3		
Strongly disagreed	5	5.6	63,76	7.815 **
Disagreed	2	2.2		
Total	**89**	**100.0**		
Continues deforestation	**Frequency**	**Percent**		
Strongly agreed	45	48.9		
Agreed	36	39.1		
Strongly disagreed	6	6.5	55,04	7.815***
Disagreed	5	5.4		
Total	**92**	**100.0**		
Poor rate of seed germination	**Frequency**	**Percent**		
Strongly agreed	46	50.0		
Agreed	38	41.3	26,17	5.991**
Strongly disagreed	8	8.7		
Total	**92**	**100.0**		
High numbers of years for vegetative growth	**Frequency**	**Percent**	82,26	7.815 ***
Strongly agreed	52	56.5		
Disagreed	**36**	39.1		
Strongly disagreed	2	2.2		

Disagreed	2	2.2		
Total	**92**	**100.0**		
Inadequate extension support/advisory services	**Frequency**	**Percent**	55,91	7.815 ***
Strongly agreed	46	50.0		
Agreed	35	38.0		
Strongly disagreed	6	6.5		
Disagreed	5	5.4		
Total	**92**	**100.0**		

(* at p<0.05, ** significant at p<0.01: *** significant < 0.001, ns not significant)

Constraints of NTFPs Marketing:

The table 5 showed that, 52.2% strongly agreed that poor roads network limited the penetration of buyers into the community which has therefore affected the commercialization of these products, 41.3% agreed that poor roads has affected NTFPs marketing, 6.5% disagreed that poor roads has not affected marketing (X^{2cal}=31,39, x2tab=5.991). In addition, as showed on table 5 lower purchasing power of buyers, reported a 57.6% strongly agreed that it affects marketing of NTFPs, 48.3% agreed as well, while 5.6% strongly disagreed that lower purchasing power of buyers has not affected the marketing of NTFPs and 2.2% disagreed (X^{2cal}=74,08, x^{2tab}=7.815). Also , table 5 showed that 41.3% of the respondents strongly agreed that inadequate number of buyers has affected marketing of NTFPs , 45.7% agreed and 9.8% strongly disagreed that inadequate number of buyers has not affected marketing and 3.3% disagreed (X^{2cal}=51,39, x^{2tab}=7.815). Next, 54.3% of the respondents strongly agreed they lacked market information ofNTFPS, 40.2% agreed similar 3.3% strongly disagreed and 2.2% disagreed lack of market information did not affect marketing of NTFPs (X^2=76,78, x^{2tab}=7.815). Moreover, 35.1% strongly agreed that lack of storage facilities has greatly affected the marketing of NTFPs in the community, 62.0 agreed, 5.4% strongly disagreed that lack of storage facilities did not affected marketing and 1.1% disagreed (X^{2cal}=86,95, $x2^{tab}$=7.815).

Table 5: Shows constraints of NTFPs marketing

Variables			**X ^{2}cal**	**X ^{2} table value**
Poor roads limiting the entry of buyers	**Frequency**	**Percent**	31,39	5.991 ***
Strongly agreed	48	52.2		
Agreed	38	41.3		
Disagreed	6	6.5		
Total	**92**	**100.0**		
Lower purchasing powers	**Frequency**	**Percent**		
Strongly agreed	53	57.6		
Agreed	31	33.7	74,08	7.815 ***
Strongly disagreed	7	7.6		
Disagreed	1	1.1		
Total	**92**	**100.0**		
Lack of buyers	**Frequency**	**Percent**		
Strongly agreed	38	41.3		
Agreed	42	45.7		
Strongly disagreed	9	9.8	51,39	7.815 ***

Disagreed	3	3.3		
Total	**92**	**100.0**		
Lack of market information	**Frequency**	**Percent**		
Strongly agreed	50	54.3		
Agreed	37	40.2	76,78	7.815 ***
Strongly disagreed	3	3.3		
Disagreed	2	2.2		
Total	**92**	**100.0**		
Lack of storage facilities	**Frequency**	**Percent**		
Strongly agreed	29	31.5		
Agreed	57	62.0	86,95	7.815 ***
Strongly disagreed	5	5.4		
Disagreed	1	1.1		
Total	**92**	**100.0**		

(** at p<0.05, ** significant at p<0.01: *** significant < 0.001, ns not significant)

Prospects of NTFPs Production and Marketing of NTFPs:

Prospects of Production:

The results on table 6 are showed below. It was noticed that 58.7% of the respondents strongly agreed that farm to market roads should be improve upon whereas 41.3% agreed (X^{2cal}=2,78, x^{2tab}=3.841). Also, 55.4% strongly agreed that there should be forest regulations that will protect direct entry of producers into the forest 41.3% agreed, 1.1% strongly disagreed and 2.2% disagreed (X^{2cal}=84,08, ^{x2tab}=7.815). From table 4.6, 75.0% strongly agreed that improving the production of NTFPs, they should be domesticated, 23.9% agreed and 1.1% strongly disagreed (X^{2cal}=2,78, x^{2tab}=3.841).

Table 6: Shows prospects of production of NTFPs

Variables			**X ^{2}cal**	**x^{2tab}**
Improve farm to market roads	**Frequency**	**Percent**		3.841 (ns)
Strongly agreed	54	58.7	2,78	
Agreed	38	41.3		
Total	92	100.0		
There should be forest regulations	**Frequency**	**Percent**		7.815 ***
Strongly agreed	51	55.4	84,08	
Agreed	38	41.3		
Strongly disagreed	1	1.1		
Disagreed	2	2.2		
Total	**92**	**100.0**		
Domestication of NTFPs	**Frequency**	**Percent**	79,06	5.991 ***
Strongly agreed	69	75.0		
Agreed	22	23.9		
Strongly disagreed	1	1.1		
Total	**92**	**100.0**		

(* at p<0.05, ** significant at p<0.01: *** significant < 0.001, ns not significant)

Prospects of Marketing:

As seen on the table 7 below, 64.1% respondents strongly agreed that storage facilities should be created in order to improve marketing of NTFPs, 35.9% agreed (X^{2cal}= 7,34, x^{2tab}=3.841). Also, 55.4% respondents strongly agreed that market information should be properly disseminated in order to improve marketing of NTFPs, 44.6 % agreed (X^{2cal}= 1.08, x^{2tab}=3.841). Base on the table below, 52.2% strongly agreed farmers should organize themselves and form cooperatives, 45.7% agreed while 2.2% strongly disagreed (X^{2cal}=40,78, x^{2tab}=5.991). Furthermore, 56.5% strongly agreed that farmers should be train on how to transform their products in order to reduce post-harvest losses and 43.5% agreed (X^{2cal}= 1.56, x^{2tab}=3.841).

Table 7: Shows prospects of marketing of NTFPs

variables			**X ^{2}cal**	**X ^{2} tab value**
Creation of storage facilities	**Frequency**	**Percent**	7,34	
Strongly agreed	59	64.1		
Agreed	33	35.9		3.841 ***
Total	**92**	**100.0**		
Proper dissemination of market information	**Frequency**	**Percent**	1.08	3.841 ***
Strongly agreed	51	55.4		
Agreed	41	44.6		
Total	**92**	**100.0**		
creation of cooperatives	**Frequency**	**Percent**		
Strongly agreed	48	52.2		
Agreed	42	45.7	40,78	5,991 ***
Strongly disagreed	2	2.2		
Total	**92**	**100.0**		
Train farmers on product transformation	**Frequency**	**Percent**		
Strongly agreed	52	56.5		
Agreed	40	43.5	1,56	3.841 (ns)
Total	**92**	**100.0**		

(* at p<0.05, ** significant at p<0.01: *** significant < 0.001, ns not significant)

DISCUSSION

Socio-Demographic Characteristics of Farmers

Sex ratio was noticed as an important socio-demographic parameter (Table 1). The results showed that the percentage of female respondents were higher 53.3% than the male which stood at 46.7%. NTFPs production, gathering and marketing has been noticed to be of a more feminine than a masculine activity which required minimal amount of energy. This finding is in conformity with works of Sunderland et al., (2004) who mentioned women are more involved in NTFPS activities than men.

Most of the respondents had attained a level on the educational ladder. About 41% of the respondents had secondary education, 33.7% had primary education, 10.9% had tertiary education and only 14.1% had no formal education. This showed that most of the respondents were educated. The high level of literacy though at lower level could help them to seek information of the price of NTFPs in the market and gathered knowledge on storage and

preservation of their products. BUCREP (2005) also agreed that the basic knowledge of the farmers could help in seeking informations. Pagiola (1999) ; Newton et al., (2016) also reported that a basic level of education by the respondents will enable the farmers to know the level of exploitation and extraction NTFPs, thus limit over exploitation and extinction of some of these species.

The majority of the respondents were below 40 years (43.5%), indication of a youthful and productive population. At this age there are expose to lots of knowledge and experience, this potential can develop solid agricultural projects that will improve the production and marketing of NTFPs (Joel et al., 2016).

With respect to household size, majority of the farmers had small household sizes of 1-5 (45.7%), this was closely followed by 6-10 (38.0%) household size (Table 4.1). This is an indication that during peak periods labour maybe solicited. With low household sizes farmers may form ngangi groups to assist one another. However, large families are also more likely to face lower per capita land availability and high dependency ratios for food requirements (Adesina et al. 2000; Mujawamariya and Karimov 2014). They may thus rely on forest resources around the communities because of the available family labour that can be utilized for NTFPs production and marketing.

Most of the labour the respondents used on their farms was family labour with the percentage of (59.8%). The family labour utilised by most of the household helped to reduce their labour cost. In most rural settings most farmers make maximum use of household labour. This is in line with works of Alfred and Fagbenro (2007) who mentioned that a high family labour could reduce household expenses on farming activities.

Farmers in Nguti Sub-division have some experiences in production and marketing of NTFPs. The relatively high experience shown by farmers in this area could be an indication that farming is an ensuring occupation that farmers could rely. This is in agreement with the findings of Adeoti (2004) who reports that continuous practice of an occupation for long period of time could lead to more experience and production.

Table 4.1 showed that (35.9 %) of the farmers had11-15 ha and (7.7%) had more than 16 ha. Farm size plays an important role in crop production as it influences the quantity and availability of food in the household at any point in time. Households with limited farmland may not be able to produce adequate food for their families, hence, rely heavily on forest resources around them as their safety net, to complement food shortage. Wunder et al., (2003) confirmed that communities around forest resources will depend on forest for their livelihoods.

The main occupation of the respondents was farming with 95.5%, and others such business and civil servants recorded 4.3%. Most farmers' households depend on NTFPs collection as compared with those into business and civil servant. Jimoh and Azeez (2002); Daneji and Suleiman (2011) supported the fact that household who are engaged in other sectors of the economy such as trading and formal employment are less likely to be dependent on NTFPs collection to supplement their earnings.

Major Non-Timber Forest Product (NTFPs) Produce and Marketed

The major NTFPs produced and marketed in this area of study were rainy season bush mango,

dry season bush mango, njangsa, bitter cola, country onion, eru and bush pepper. This is as a result of the high market demand of these products within and beyond the national territory. As such it improves on livelihoods inhabitants. The highest NTFP that was produced and marketed was the dry season bush mango (*Irvingia wombulu*) at 31.5%. This is due to the fact that this *Irvingia wombulu* is available off season of NTFPS collection, thus most farmer exploited lack season and sold to buyers from neighboring towns from Nigeria and Cameroon at a higher price. Eru (3.3%) was the least that was produced and marketed because this NTFP was produced mainly for home consumption. This is in line with Nkefor et al., (1998) who noticed low percentage propagation for the domestication of eru. It is important to note that the harvesting techniques employed by most of the inhabitants are by pulling the plant destroyed right down to the roots.

Opportunities of Production and Marketing of Non-Timber Forest Products

In respect to the opportunities of production and marketing of NTFPs, majority of the respondents indicated that through the sales of these products they' have been able to raise more income from NTFPs. NTFPs also provide an extra income when agricultural produce failed. This finding is in accordance with works of Angelson and Wunder, (2003); Neuman and Hrisch, (2000), who reintegrated that NTFPs are considered a safety net to fill in the gaps when there is an agricultural shortfall.

Seasonal employment was another opportunity from the sale of NTFPs were (54.3 %) strongly agreed that the production and marketing of NTFPs has led to seasonal employment. During this period persons are being hired to collect and transform some of these products, thus, earning an extra income. This is in conformity with Schreckenberg et al., (2006) and FAO, (2010), who reported that most rural households makes impressive income during peak season of NTFPs production. Another finding noticed is that, (55.4%) strongly agreed that one of the greatest opportunities for NTFPs production and marketing was the fact that the products could be stored and sold later during off season which fetches more income for the household. During the rainy season, the NTFPs are saturated in the market and are sold at giveaway prices. This finding is in line with Belcher and Schreckenberg, (2007) who reported that unpredictability could also be caused by demand punctuations as a result of changing trends.

High demand was indicated as an opportunity from the sale of NTFPs (67.0 %). The fact that most farmers in the rural areas and urban center rely solely on NTFPs, these products are bought for consumption while others are being exported and use for pharmaceutical industry. This is in accordance with Guedje et al., (1998) who said non-Timber Forest products ensure the maintenance of food security for many rural households. These products are used as medicines, feed for animals, food and income to meet basic necessities (Ingram et al., 2016).

Constraints of Production and Marketing of NTFPs

From the results, majority of the respondents strongly agreed that unsustainable harvesting of NTFPs affected production. These results showed that commercialization of NTFPs has both positive and negative effects for livelihoods and conservation (Marshall et al., 2006); and striking the balance between these two is crucial for sustainability (Arnold and Perez, 2001). Some of the positive role noticed for commercialization includes: alternative income generated from sales of NTFPs, revenues from exported products and increase in supply of NTFPs for consumption in the market. On the other hand, we noticed negative effects of commercialization which includes: stock degradation, over exploitation and the fact that most of the products could be depleted and farmers could cover long distances in search and collect the NTFPs. Marshall et al. (2006)

observed similar overharvesting trends influenced by increased commercialization in Mexico and Bolivia. Sunderland et al., 2004 also observed similar trends in the Takamanda rainforest of Cameroon.

Continuous deforestation was reported as a constraint for the production of NTFPs. With the increase in population growth, there's bound to be a lot of pressure on the forest for food, construction of houses and establishment of plantation to better their livelihoods. This is in line with Arnold and Perez, (2001); Belcher et al., (2005) who reported that although NTFPs are an important source of subsistence and cash income, there is growing concern regarding the fact of overharvesting. This is fuelled by an increasing population and market demand for these products.

Also, the long duration observed for vegetative growth is a constraint for NTFPs production. Most of the species take longer period to fruits. Therefore, the need for domestication of some of these NTFPS is paramount to reduce pressure on natural production. This is in accordance with Leaky and Izac, (1996) and Nkefor et al., (1998) who mentioned that domestication is also crucial for improving genetic quality in order to realize higher yields, extended periods of production, and the development of tolerance to variable temperature and soil conditions. Therefore, domestication of NTFP species to enrich and sustain stock is essential for sustainable commercialization and marketing (Vantomme et al., 2002).

Furthermore, inadequate extension service was also observed as a constraint as (50.0%) strongly agreed that it affects production of NTFPs. The consequence of overexploitation of the forest resources are also due to the lack of extension agents and poor follow-up of laws of forest governance. This observation in agreement with Pandit, (2001); Pandit and Thapa, (2004) whose mentioned that this situation is severe in community forest managed by the councils where access is open. This is also in conformity with Moobi and Oladele (2012) whose results showed that about 75% of the farmers indicated the need for communication strategies that facilitate effective flow of information between government agencies and farming communities. This may be the results of inappropriate ratio of government agencies to farmers. In this situation, the government extension agents may not be able to visit all farmers within a week, hence productivity level declines.

Inadequate number of buyers was also a constraint (45.7%) agreed that it has affected the marketing of NTFPs. This is because of the socio-political crisis and poor farm to market roads that limits marketing of NTFPs. This is in accordance with Anold et al, (2001) who said that the socio-political crises have greatly affected the marketing of goods in rural areas for fear of unknown.

Another aspect is the inadequate number of storage facilities which was noticed as a main constraint of marketing of NTFPs as (62.0%) agreed. Cong et al., (2006) stated that due to the inadequate number of storage facilities, farmers tend to use traditional techniques which are not efficient resulting to high losses and reduction in the quality of produce for small-scale farmers.
Inadequate of transportation, resulting from bad road network in the subdivision, (52.2%) strongly agreed that poor roads prevent buyers from coming into the villages and also limited transportation of produce to better markets. However, it might have retarded quick distribution of produce after harvesting especially perishable goods. Thus, less income that could be made from sales of low quantity and poor-quality products. This is in conformity with Adeleke et al.,

(2010) who stated that road systems are the most serious infrastructural constraints faced by the agricultural and forestry sectors. This observation was also reported by Marshall et al., (2006) who found out that although most of the villages accessible by road during dry seasons but the conditions are very different in the rainy season.

Inadequate access to credit turned out to be a major barrier to NTFP producers in the subdivision as (48.3%) agreed. The inadequate access to credit may probably be due to the fact that most of the farmers are not into cooperatives and small common imitative groups (CIGs) which they could get micro loans for their activities. Most of the farmers lack information about available sources of funds or credits to exploit. According to Ozowa (1995) he mentioned that awareness of existing loan facilities could be linked to the high illiteracy rate amongst most rural farmers. Adeleke et al., (2010) stated that the main reason for commercial banks not to lend money to agricultural enterprises is as a result of low reliability of the NTFPS sector.

Furthermore, majority (54.3%) of the farmers did not have access to marketing information. Farmers had very little knowledge about the existing and potential markets for NTFPs. This result is in accordance with Dorward and Kydd (2005), who reported that businesses in rural areas are attributed by weak information on potential market players, prices and innovations. Saxena (2008), further stated that producers are often in agricultural practices, but highly limited in effective and efficient marketing strategies.

Prospects of Production and Marketing of Non-Timber Forest Products

With respect to domestication of NTFPs (75.0%) strongly agreed that these products should be domesticated in order to improve production. This is in accordance with Leaky et al., (2005); Belcher et al., (2005) who demonstrated that domestication is an alternative strategy to reduce pressure on the wild products and at the same time generating income as well as it could play a vital role in conservation.

To reduce the market constraints, the farmers in Nguti Sub-division have suggested better and frequent transport facilities for better communication, more financial support to encourage cooperative based NTFP cultivation activities, and enhanced access to market as essential initiatives. This finding is in conformity with Shiba, (2010) who reported that sufficient government or NGO interventions to eliminate constraints could play a positive role in assisting the villagers to generate more income. For example, micro-credit or small-scale loans from government departments, NGOs, or banks could be arranged to develop NTFP-based enterprises designed to generate income. Moreover, enhancing the villagers' access to market information relevant to NTFPs could be achieved through forest extension agents (currently no such personnel exist) appointed by the forest department. However, (55.5%) strongly agreed that forest regulations should be enacted in order to reduce pressure on the forest as people will not have the liberty of entering the forest at will to collect NTFPs. This is in line with (Belcher, 2007) who reiterated that merely taking these initiatives without considering the policy issues, and taking related steps such as creating and effectively implementing people-oriented NTFP management plans and defining land and property rights, may only accelerate the current unsustainable extraction practices. Moreover, when organizational interventions are undertaken, they should include plans for managing specific NTFPs.

Base on the findings, (55.2%) of NTFPs producers and marketers strongly agreed that there should be proper dissemination of market information. More market knowledge tends to increase

villagers' income from NTFPs, as observed in Mexico and Bolivia (Marshall et al., 2006). Thus, enhancing the villagers' market knowledge could be an effective avenue for NTFP-based interventions. The villagers' market knowledge is greatly influenced by different socioeconomic factors relating to households and markets (Marshall et al., 2006). The results of the analysis on the production and marketing prospects also include creation of storage facilities and the fact that farmers should be trained on product transformation in order to minimize spoilage and add value to some products before commercialization. Only a small percentage of what is harvested from the forest is eventually utilized, meanwhile, a larger percentage is wasted during storage and processing. This is in accordance with Babalola, (2009) and Shrestha et al., (2020), who mentioned that lack of modern technology for processing and storage is one of the major problems associated with the production and marketing of NTFPs. Most of the raw NTFPs got rotten during storage because they were not appropriately processed. This leads to wastage of the resources and time spent in collection.

CONLUSION

Results from the study in Nguti Sub-division on prospects of production and marketing of NTFPs revealed that NTFPs play an important role in the livelihood of rural and forest dwelling communities. Respondents from the study areas depend on those NTFPs for their nutrition and health care. It also provided food and generated income to most household who depend on NTFPs production and marketing for their livelihoods. During scares period due to over exploitation, poor seasonal production and settlement encroachment, usually resulted to devastating consequence with most of the farmers left hungry. Domestication techniques should be encouraged on farms and gardens. Fast growing species should be encouraged on farms and garden to overcome scarcity periods. Information on production, exploitation and marketing information should get to the farmers in due time.

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Whitefly *Bemisia tabaci* (Hemiptera: Aleyrodidae) Cryptic Species is Closely Associated with Mungbean Yellow Mosaic Virus (Begomovirus: Geminiviridae) Hotspot Regions and Biochemical Changes in Host Plants

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Abstract:
The Greengram (Vigna radiata (L) Wilczek) or Mungbean is an important pulse crop cultivated in India. Mungbean Yellow Mosaic Virus (Begomovirus; Geminiviridae) is one of the majors constrains for the productivity and it is exclusively transmitted by the vector whitefly Bemisia tabaci (Gennadius), (Hemiptera: Aleyrodidae). The study reveals that the genetic diversity of B.tabaci is influenced by the begomovirus infection. The sequence analysis of Mitochondrial Cytochrome Oxidase (mtCOI) subunit I PCR products from 21 individual samples shown that exist of B. tabaci cryptic species Asia II 8 and Asia I. Where the Asia II 8 was closely associated with MYMV hotspot regions and Asia I was closely associated with vegetable crops grown in Tamil Nadu. Further laboratory experiment confirmed that the preference of B. tabaci (Asia II 8) was influenced by the MYMV infection status and the non-viruliferous whiteflies settled more (55%) on infected plants and the viruliferous whiteflies settled more (62.7%) on non-infected plants. Subsequent biochemical analysis revealed that the preferences are associated with biochemical changes after the virus infection in the plants. Found that the protein, phenol, peroxidase and polyphenol peroxidase contents were increased and the chlorophyll and total sugars were decreased after MYMV infection in greengram. MYMV specific primer was used to detect the virus in greengram and whiteflies.

INTRODUCTION

Mungbean yellow mosaic virus (MYMV) is a serious production constraint in all legume crops growing regions of Indian subcontinent and it is exclusively transmitted by the vector whitefly Bemisia tabaci (Gennadius), (Hemiptera: Aleyrodidae). The affected plants are with small yellow irregular specks, mosaic, leaf mottling, yellowing and drying and causes about 80-100% yield loss (Nene 1973) to the tune of $ 300 million every year (Varma et al. 1992; Varma and Malathi 2003). Two strains of MYMV had been reported in India (Tsai, 2013) one is Mungbean Yellow Mosaic India Virus (MYMIV) which is more predominant in northern, central and eastern regions (Usharani et al. 2004) and another one is MYMV in southern region particularly in Tamil Nadu (Karthikeyan et al. 2004; Girish and Usha 2005; Haq et al. 2011). Both the strains are transmitted by the vector B. tabaci in a persistent and circulative manner (Markham et al. 1994).

B.tabaci is a polyphagous, distributed worldwide and has species complexity; about 40 cryptic species had been reported so far (Hu et al., 2017). First B. tabaci was recorded in India during 1905 from cotton host (Rao et al., 1989; Misra and Lambda, 1929). Subsequent to this, the invasive biotype-B was discovered in South India (Banks et al., 2001; Rekha et al., 2005) Shankarappa et

al., 2007) and it changed the disease empidemiology in tomato and population dynamics of indigenous B. tabaci (Banks et al., 2001). Similarly, Palaniswami et al., (1995) observed exist of B. tabaci biotype in cassava and differed in transmission efficiency and feeding preference (Lisha et al., 2003; Palaniswami and Henneberry, 2011). The presence of host specific cluster in B. tabaci was reported and they classified into Group I, Group II and Group III (Sharma et al., 2008). Based on the mtCOI sequence analysis found 5 cryptic species in India (Chowda - Reddy et al., 2012; Ellango et al., 2015; Prasanna et al., 2015; Ram Kumar et al., 2017). However, B. tabaci cryptic species Asia II 1 was predominant in North India and Asia II 8 was predominant from south India (Nair et al., 2017).

The plant viruses are mostly transmitted by insect vectors for which the virus alter the behaviour of the vector in a manner to spread the disease from plant to plant by evolving special mechanism (Fereres and Moreno 2009; Ng & Falk 2006; Hogenhout, et al. 2008). Some of the recent studies demonstrated that the virus could manipulate the vector behaviour in ways favourable to the spread of viruses (Ingwell et al. 2012; Rajabaskar et al. 2013a, 2013b, 2013c; Roosien et al., 2013). With this view a study was carried out to identify cryptic species of B.tabaci in MYMV hotspot regions (Tamil Nadu, India) in greengram and to understand the preference of that cryptic species with infection status of MYMV and the associated biochemical changes.

MATERIALS AND METHODS

Sample Collection

B.tabaci adults were collected from MYMV hotspot regions of Tamil Nadu viz., Vamban, (Puthukottai), Aaduthurai (Thanjavur), Navalurkuttapadu (Trichy), Panpolil (Thirunelvli) and Coimbatore. The whiteflies were collected at the early morning hours by using aspirator then transferred to 1.5 ml eppendorf tubes containing 95 per cent ethanol with the help of camel hair brush (000 size) and stored in -20 °C until for further use (Ellango et al.,2015).

Vector Rearing

B.tabaci was reared as described by Butter and Rataul, (1977).The pure culture of whiteflies, B. tabaci (Asia II 8) was originally collected from the greengram (variety CO 8) field (Department of Pulses, Coimbatore) with help of an aspirator (50 ml) and maintained in a bugdorm (MegaView, Taiwan) under the screenhouse conditions. The brinjal (Solanum melongena L) plants (variety CO 6) were used for rearing whiteflies and fresh brinjal plants were introduced to the cage at 10 days interval and allowed to move the whiteflies to new one and the old plants were removed periodically. The adult non viruliferous whiteflies were collected 5 months after release and used for all the experimental studies. The whiteflies adult samples were taken from the bugdorm randomly and the DNA was analysed using mtCOI primer, sequenced and the cryptic species was identified by exploring NCBI database.

DNA Isolation

Five B.tabaci were analysed from each field. DNA was extracted from single whitefly by using lysis buffer **(**Zeidan and Czosnek, (1991); Singh et al. 2012). The DNA was extracted from single adult whitefly by using lysis buffer (5 µl Tris 1M (pH 8) @ 100 µl , 1 µl EDTA 0.5 M (pH 8) @ 20 µl, 5 µl Igepal (Triton X 100) @ 100 µl , 50 µl proteinase-K (20 mg/ml) @ 1000 µl, 939 µl Distilled water @ 18780 µl). Briefly a petri dish (90mm dia) was first wrapped up with aluminum foil (Mirage foil-10.5µ thickness) then with parafilm (American National Can^{TM}). 5 µl of lysis buffer was spotted on the centre of the parafilm. A single adult whitefly was placed on the buffer spot using camel hair brush (size 000) and crushed with edge of a sterile PCR tube (1.5ml). After crushing, the entire

content (including the washing from edge of the PCR tube) was transferred to sterile PCR tube (1.5.ml) and kept in an ice box for 5 minutes. Subsequently it was incubated in a water bath (Bio Equipment,) at 65°C for 15 minutes followed by 95°C for 10 minutes then kept in a refrigerator () for 3 min. Finally, the sample was vortexed for five seconds and proceeded for PCR analysis.

Sequencing of PCR Product:

The amplified PCR product (20 µl) was sent to the sequencing facility, J.K Scientific Company, Coimbatore,TN,India for single pass DNA sequencing with mtCOI forward and reverse primers (5 µl for each sample). The sequenced data were assembled and analysed as described by Hall, 1999 using a software programme (Bioedit v 7.0.5). Multiple alignments and predicted amino acid sequence alignment were done in CLUSTAL X programme. After that trimmed sequence data was analysed in the NCBI (). The neucleotite sequence similarity was checked with the data base available in the GenBank (NCBI). Then the dendrogram was constructed using the neighbour-joining method with bootstrapping (500 replicates) in MEGA software version 4.0 (Tamura et al., 2007).

Virus Maintenance

The non-viruliferous B.tabaci adults were collected from the brinjal plants reared under the bugdorm and kept 30 min in a petridish for starvation. Ten whiteflies' adults were shifted to clip cage (1.5 cm x 1.3 cm) and fixed on MYMV infected greengram plants (symptomatic) for virus acquisition. After 24 h of Acquisition Access Period (AAP), shifted to 10 days old greengram seedlings and kept 24 h for inoculation. From these symptomatic leaves were used for bioassay experiments. The presence of MYMV in the whiteflies and greengram plants was checked periodically using PCR analysis with MYMV specific primers (RHA-F 5' TCAAGCTCCCGGTGCATGTTGCA 3'and AC-abut 5' GTAAAGCTTTACGCATAATG 3').

Virus -Vector- Host Interactions

Settling Preference:

The settling preference of B. tabaci, Asia II 8 was examined in relation to MYMV infection status in greengram. About 500 B.tabaci adults were collected from the brinjal plant which was maintained under the screenhouse. After 1 h of starvation each 20 whiteflies were shifted into the bottom of petridish (125mm dia x --h) containing MYMV infected and non-infected leaves separately. The covering lid top portion was removed and fixed with a nylon mesh (diameter, 34 mm; mesh size, 63 µm). The infected non infected greengram leaves were collected from the plants maintained at the screenhouse and a leaf bouquet was prepared. The detached trifoliate leaf's petiole was covered with moist cotton in order to avoid wilting of leaf. Then the bouquet leaf (facing the abaxial portion upper side) was kept into the petridish over a moist filter paper (No.46). The 20 whiteflies were placed into petridish, with the help of camel hair brush after 5 min refrigeration. Then the areana was covered with lid and kept inside a Enviromental plant growth chamber (Percival, USA). The experiment was completely randomized with four tratments consist of viruliferous and non-viruliferou B.tabaci and MYMV infected and healthy greengram leaves. Each treatment was replicated for 15 times. Number of whiteflies settled on the infected and non-infected leaves were observed 1, 3, 6, 12 and 24 h after release. The mobile torch light was used for counting under dark condition. After the bioassay the samples were kept in a zip lock bag individually, properly labeled and stored under -80 for further biochemical and PCR analysis.

Biochemical Analysis

The chlorophyll content present in the MYMV infected and healthy greengram leaves were analysed as described by Bruinsona, (1963), the total carbohydrate was estimated using anthrone method (Hedge and Hofreiter, 1962). Phenols were estimated using folin reagent as described by Malick and Singh, 1980, Protein was estimated using modified Lowry method (Hartree, 1972).

Statistical Analysis

The data observed from preference and the associated biochemical changes in the infected and non-infected plants were analyzed with student's t-test by using SPSS Statistics ver.17.0.

RESULTS

B.tabaci Cryptic Species Identification in MYMV Hotspot Regions

B.tabaci adult samples were collected from 5 major MYMV hotspot regions of Tamil Nadu. A summary of geographical locations, host plants, date of collections, species identified and the gene bank accession number is presented in Table 2. The sequence analysis of Mitochondrial Cytochrome Oxidase (mtCOI) subunit I PCR products from 21 individual sample shown that presence of B. tabaci cryptic species Asia II 8 and Asia I where Asia II 8 is closely associated with MYMV hotspot regions and Asia I is closely associated with vegetable crops grown in Tamil Nadu (Table 1).

Table.1. Details of survey, sample collection, host, locations and Bemisia tabaci genetic group in MYMV hotspot regions of Tamil Nadu.

S.NO	Sample Name	Genetic Group	Host	Place	Coordinates	Collection Date	Genbank Accession No
1.	VBNBG	Asia II 8	Vigna mungo	Vamban	N 11° 30' , E 79° 26'	6.3.18	MH374156
2.	VBNGG	Asia II 8	Vigna radiata	Vamban	N 11° 30' , E 79° 26'	6.3.18	MH374157
3.	ADTBG	Asia II 8	Vigna mungo	Aduthurai	N 10.9985° , E 79.4801°	7.3.18	MH356716
4.	TRYGG	Asia II 8	Vigna radiata	Trichy	N 10°45' , E 78°36'	7.3.18	MH374155
5.	CBEBG	Asia II 8	Vigna mungo	Coimbatore	N 11° 07' ,E 76° 59'	28.12.17	MH374139
6.	CBEGG	Asia II 8	Vigna radiata	Coimbatore	N 11° 07' ,E 76° 59'	28.12.17	MH374148
7.	CBERG	Asia II 8	Cajanus cajan	Coimbatore	N 11° 07' ,E 76° 59'	4.10.17	MH374152
8.	CBEHG	Asia II 8	Macrotyloma uniflorum	Coimbatore	N 11° 07' ,E 76° 59'	20.12.17	MH374150
9.	CBEGNUT	Asia II 8	Arachis hypogaea	Coimbatore	N 11° 07' ,E 76° 59'	22.12.17	MH374149
10.	CBEBRI	Asia 1	Solanum melongena	Coimbatore	N 11° 07' ,E 76° 59'	19.9.17	MH374141
11.	CBEBRI1	Asia 1	Solanum melongena	Coimbatore	N 11° 07' ,E 76° 59'	20.9.17	MH374142
12.	CBEBI	Asia 1	Abelmoschus esculentus	Coimbatore	N 11° 07' ,E 76° 59'	13.10.17	MH374140
13.	CBECALI	Asia 1	Brassica oleracea var. botrytis	Coimbatore	N 11° 07' ,E 76° 59'	31.10.17	MH374143
14.	CBECAP	Asia 1	Capsicum annuum	Coimbatore	N 11° 07' ,E 76° 59'	14.9.17	MH374144
15.	CBECWA	Asia 1	Vigna unguiculata	Coimbatore	N 11° 07' ,E 76° 59'	4.11.17	MH374145
16.	CBECT	Asia 1	Gossypium hirsutum	Coimbatore	N 11° 07' ,E 76° 59'	8.10.17	MH374146
17.	CBECU	Asia 1	Cucumis sativus	Coimbatore	N 11° 07' ,E 76° 59'	14.12.17	MH374147
18.	CBEMM	Asia 1	Cucumis melo	Coimbatore	N 11° 07' ,E 76° 59'	16.12.17	MH374151
19.	CBETOM	Asia 1	Solanum lycopersicum	Coimbatore	N 11° 07' ,E 76° 59'	19.9.17	MH374153

20.	CBETOM1	Asia 1	Solanum lycopersicum	Coimbatore	N 11° 07' ,E 76° 59'	20.9.17	MH374154
21.	PAPGG	Asia II 8	Vigna mungo	Panpoli	N 8°67', E 77° 70'	6.3.18	MH476485

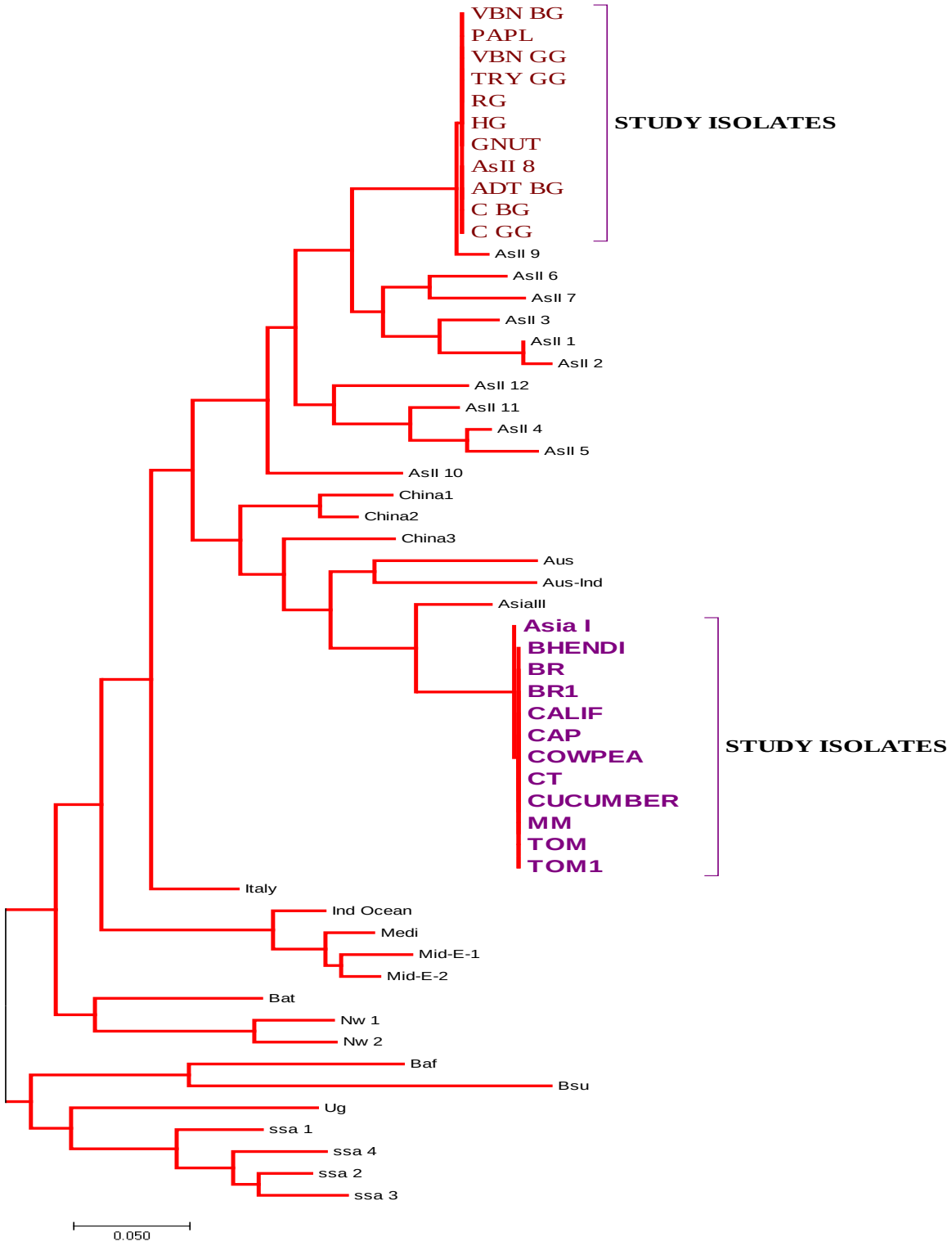

Fig.1.Phylogenetic dendrogram based on mtCOI partial sequences of Bemisia tabaci genotypes

Phylogenetic tree generated from aligned partial mtCOI nucleotide sequences of Bemisia tabaci genotypes with other selected whitefly genotypes. Tree was generated by neighbor joining

method by aligning the sequences in MEGA 7 ClustalW. Vertical branches are arbitrary; horizontal branches are proportional to calculated mutation distances; values at nodes indicate percentage boot straps values (1000 replicates).

A phylogenitic relationship of 21 B. tabaci samples from 5 major locations was presented in the Table 2. The Bayesian phylogenitic analysis revealed that the B.tabaci sequences were grouped into two different clades (Fig 1). The sequences were characterized and assigned to two groups as described by Dinsdale et al., (2010). When the sequences of about 605bp (the maximum sequence which got aligned) were compared, the whitefly populations VBNBG, VBNGG, ADTBG, TRYGG, CBEBG, CBEGG, CBERG, CBEHG, CBEGNUT and PAPGG showed 99 % identity with Asia II 8 genotype and CBEBRI, CBEBRI1, CBEBI, CBECALI, CBECAP, CBECWA, CBECT, CBECU, CBEMM, CBETOM and CBETOM1 showed 99 % identity with Asia I genotype (Table 1).

Table.2. Preference of non-viruliferous B. tabaci (Asia II 8) to MYMV infected and healthy Greengram hosts

Replication	% Settling preference at different time intervals									
	Infected	Healthy	Infected	Healthy	Infected	Healthy	Infected	Healthy	Infected	Healthy
	1 h	1 h	3 h	3 h	6 h	6 h	12 h	12 h	24 h	24 h
R1	15	10	50	50	65	40	75	50	85	70
R2	10	25	25	30	50	45	40	40	55	65
R3	10	15	35	30	30	40	50	50	70	45
R4	5	5	30	20	20	35	40	40	55	55
R5	10	10	30	15	50	40	55	45	75	55
R6	5	5	25	20	60	30	50	50	70	50
R7	20	20	20	30	35	35	40	25	45	45
R8	15	10	25	40	45	30	55	15	50	35
R9	25	20	40	20	50	30	55	60	40	35
R10	10	10	15	15	35	20	55	45	45	60
R11	15	15	20	20	40	40	50	50	70	50
R12	20	20	20	10	35	40	60	55	55	45
R13	20	25	25	20	25	30	30	30	25	40
R14	30	25	30	25	25	20	40	40	50	50
R15	15	20	30	15	35	25	50	55	35	45
Mean	15.00	15.67	28.00	24.00	40.00	33.33	49.67	43.33	55.00	49.67
Standard Error	1.83	1.82	2.28	2.73	3.38	1.99	2.78	3.15	4.23	2.60
P value	0.789		0.270		0.137		0.027*		0.002**	

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

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

MYMV-Bemisia tabaci (Asia II 8)-Mungbean Interactions

Preference of B.tabaci (Asia II8) Pertaining to MYMV Infection Status:

The per cent preferences of non-viruliferous and viruliferous B.tabaci (Asia II8) to MYMV infected and healthy greengram plants were given in Table 4 & 5. The result indicated that the per cent settling of non-viruliferous whiteflies was 55 % on infected plants and 49.67 % on healthy plants 24 h after release (Table 4). The per cent settling of viruliferous whiteflies was 49.67 % on infected plants and 62.67% on healthy plants 24 h after release (Table 5). The preference was statistically

significant at 12 h (t = 1.571, d.f. = 28, P=0.027) and 24 h (t = 3.374, d.f. = 28, P=0.002) after release for non-viruliferous whiteflies and the preference was significant at 24 h (t = 1.071, d.f. = 28, P=0.029) after release for viruliferous whiteflies (Table 2 & 3).

Table.3. Preference of viruliferous B. tabaci (Asia II 8) to MYMV infected and healthy Greengram hosts

Replication	% Settling preference at different time intervals									
	Infected	Healthy	Infected	Healthy	Infected	Healthy	Infected	Healthy	Infected	Healthy
	1 h	1 h	3 h	3 h	6 h	6 h	12 h	12 h	24 h	24 h
R1	10	15	50	50	40	65	50	75	70	65
R2	25	10	30	25	45	50	40	40	65	55
R3	15	10	30	35	40	30	50	50	45	70
R4	5	5	20	30	35	20	40	40	55	55
R5	10	10	15	30	40	50	45	55	55	75
R6	5	5	20	25	30	60	50	50	50	70
R7	20	20	30	20	35	35	25	40	45	45
R8	10	15	40	25	30	45	15	55	35	50
R9	20	25	20	40	30	50	60	60	35	65
R10	10	10	15	15	20	35	45	55	60	45
R11	15	15	20	20	40	40	50	50	50	70
R12	20	20	10	20	40	35	55	60	45	75
R13	25	20	20	25	30	25	30	30	40	60
R14	25	30	25	30	20	25	40	40	50	80
R15	20	15	15	30	25	35	55	50	45	60
Mean	15.67	15.00	24.00	28.00	33.33	40.00	43.33	50.00	49.67	62.67
Standard Error	1.82	1.83	2.73	2.28	1.99	3.38	3.15	2.85	2.60	2.84
P value	0.798		0.266		0.744		0.633		0.049*	

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

Biochemical Analysis of MYMV Infected and Healthy Mungbean Plants

Chlorophyll:

The result showed that the chlorophyll-A content was ranged from 0.103 to 0.207 mg g^{-1} in healthy plants and 0.06 to 0.11 mg g^{-1} in MYMV infected greengram plants (t= 2.7, df= 8, p= 0.03), the chlorophyll-B content was ranged from 0.224 to 0.280 mg g^{-1} in healthy plants and it was 0.013 to 0.073 mg g^{-1} in infected plants (t= 15.528, df= 8, p= 0.001) and the total chlorophyll content in healthy leaves was ranged from 0.224 to 0.280 mg g^{-1} and it was 0.105 to 0.149 mg g^{-1} in infected leaves (t= 10.038, df= 9.69, P=0.001). The chlorophyll-A (0.14), chlorophyll-B (0.009) and total chlorophyll (0.009) content were higher in healthy plants compared to MYMV infected plants where the chlorophyll-A (0.01), chlorophyll-B (0.01) and total chlorophyll (0.01) and these were statistically significant (Table 4)

Table4.4 Chlorophyll content in healthy and MYMV infected Greengram leaves

Replication	Chlorophyll- a content (mg g^{-1})		Chlorophyll -b content (mg g^{-1})		Total chlorophyll content (mg g^{-1})	
	Healthy	Infected	Healthy	Infected	Healthy	Infected
1	0.129	0.062	0.224	0.043	0.224	0.105
2	0.149	0.105	0.280	0.038	0.280	0.143
3	0.103	0.097	0.262	0.052	0.262	0.149
4	0.207	0.114	0.251	0.013	0.251	0.127
5	0.131	0.070	0.258	0.073	0.258	0.143
Mean	0.144	0.090	0.255	0.044	0.255	0.133
S.E	0.017	0.010	0.009	0.010	0.009	0.008
P value	0.027*		0.001**		0.001**	

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

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

Protein, Total Sugars and Phenols:

The protein content present in the MYMV infected and healthy greengram leaves are presented in the Table 5. It was varied from 0.98 to 1.76 mg/100 mg fresh wt. and in infected plant total protein was 1.16 to 1.92 mg/100 mg fresh wt. The protein content was more in MYMV infected leaves (1.7 mg/100 mg fresh wt) and compared to healthy leaves (1.7 mg/100 mg fresh wt) which is statistically significant (t= 2.145, df= 8, P= 0.064) (Table 7).

Table.5. Total protein, total sugars and phenol content in healthy and MYMV infected Greengram leaves

Replication	Protein (mg 100 mg^{-1})		Total sugars (mg 100 mg^{-1})		Phenol content (µg / g)	
	Healthy	Infected	Healthy	Infected	Healthy	Infected
1	1.35	1.87	4.64	2.34	0.32	0.79
2	0.98	1.34	2.76	3.12	0.18	0.65
3	1.12	1.72	5.43	2.74	0.34	0.88
4	1.76	1.64	4.26	2.63	0.25	0.26
5	1.45	1.92	3.87	3.21	0.21	0.57
Mean	1.332	1.698	4.192	2.808	0.260	0.630
S.E	0.135	0.103	0.441	0.160	0.031	0.107
P value	0.064		0.017*		0.009**	

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

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

The total sugars were higher in healthy leaves (4.19 mg/100 mg) which is statistically significant (t= 2.996, df= 8, P= 0.017) compared to MYMV infected leaves (2.81 mg/100 mg (Table 7).

The phenol content was higher in infected leaves (0.63 µg / g) and it is statistically significant (t= 3.396, df= 8, P= 0.009) whereas the phenol content was lower in healthy leaves (0.26 µg / g) (Table 7).

Peroxidase and Polyphenol Oxidase:

The peroxidase and polyphenol oxidase activities in the MYMV infected and healthy leaves are presented in the table 6. The peroxidase content was higher in infected leaves (42.4 units / min) and it is statistically significant (t= 0.808, df= 8, P= 0.443) whereas the phenol content was lower in healthy leaves (32.4 units / min) (Table 8). The polyphenol peroxidase content was higher in infected leaves (6.4 units / min) and it is statistically significant (t= 2.587, df= 8, P= 0.032) whereas the phenol content was lower in healthy leaves (3.6 units / min).

Table.6. Peroxidase and Polyphenol oxidase content in healthy and MYMV infected greengram leaves

Replications	Peroxidase (units/minute)		Polyphenol oxidase (units/minute)	
	Healthy	Infected	Healthy	Infected
1	10.26	13.27	4.37	5.34
2	36.71	48.62	1.28	6.12
3	54.28	62.58	5.21	4.23
4	33.12	52.85	2.63	7.82
5	27.16	34.61	4.26	8.24
Mean	32.306	42.386	3.550	6.350
S. E	7.125	8.557	0.705	0.752
P value	0.0443*		0.032*	

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

DISCUSSION

Genetic Diversity of Whiteflies

Cryptic species composition and their diversity within the B. tabaci complex are the critical factors for developing sustainable and effective approaches for B. tabaci and MYMV management in pulses. The genetic diversity of whitefly was presented in (Fig 1) and Asia II 8 was found to be predominantly associated in the MYMV hotpot areas of Tamil Nadu and Asia I was closely associated with the vegetable ecosystem. These close association might be influenced by the virus for its own spread and survival () and this could be evidenced from the previous works where the introduction of new bio type had displaced the indigenous biotype in tomato-ToYLCV pathosystem in India and that affected the disease epidemiology (Ramappa et al., 1998; Colvin et al., 2006; Banks et al.,2001)

The genetic diversity of B.tabaci and its complexity had been reported earlier from India on different hosts (Ramappa et al., 1998; Rekha et al., 2005; Chowda-Reddy et al., 2012, Prasanna et al. 2015; Ellango et al., 2015; Nair et al., 2017). They followed mitochondrial COI method (Frohlich et al., 1999 and Brown, 2000) which is widely accepted and differentiation was on the basis of nucleotide sequence of mitochondrial cytochrome oxidase gene subunit I (mtCOI). They documented exists of 7 cryptic species in India viz., Asia I, Asia II 1, Asia II 2, Asia II 5, Asia II 7, Asia II 8 and MEAM 1.

In the present study showed that Asia II 8 was predominant in MYMV hotspot regions and Asia I was more predominant in vegetables crops with a possibility of associating other begomovirus which needs to be explored further. Similar findings were reported earlier (Ellango et al., 2015; Prasanna et al., 2015; Nair et al., 2017 and) where they reported that Asia II 8 population was documented in greengram and blackgram from south India and Asia I population was reported in eggplant (Prasanna et al., 2015) and cotton (Ellango et al., 2015) in Tamil Nadu, Karnataka and

Maharashtra. Considering the record of whitefly population in different crops in India, limited information is available on the cryptic species involved in MYMV transmission in pulses.

MYMV-*Bemisia tabaci* (Asia II 8)-Mungbean Interactions

Preference of B. tabaci (Asia II 8) Pertaining to MYMV Infection Status:

The result shown that the preference of non-viruliferous B.tabaci (Asia II8) adults was greater towards MYMV infected plants compared to non-infected plants. This might be due to the influence of virus on vector behaviour in order to spread the disease in the field condition. Similar results were reported especially persistently transmitted pathosystem viz., aphid-leuteovirus pathosystem (Eigenbrode et al.,2002;2017;Jiménez-Martínez et al., 2004; Srinivarsan et al., 2008; Werner et al.,2009; Rajabaskar et al.,2013a,2013b, 2013c; 2014; Ingwell et al., 2013), whitefly-begomovirus pathosystem (Liu et al.,2010; Moreno-Delafuente et al. 2013; Fang et al.,2013; He et al.,2015; Fereres et al.,2016; Legarrea et al., 2016; Shi et al.,2018) and thrips-tospovirus pathosystem (Maris et al., 2004; Ogada et al.,2012; Shrestha et al., 2012; Shalileh et al., 2016; Daimei et al., 2017; Wilson et al., 2017).

The volatiles and bio-chemicals components present in the plants are being altered by the virus after entering into the plants which would influence the host selection behaviour and fitness the vector (Bosque-Perez & Eigenbrode, 2011; Eigenbrode et al., 2017). It is important to consider that MYMV is a persistent circulative virus, this would have influenced the transmission, behavior, and preference B.tabaci, with a positive effects on viral dissemination, evidencing coevolution between virus and vector species (Eigenbrode et al., 2002; Bosque-Perez & Eigenbrode, 2011; Eigenbrode et al., 2017).

Biochemical Changes Pertaining to MYMV Infection Status

The biochemicals components viz., chlorophyll, phenols, protein, total sugars, peroxidase and polyphenoloxidase were analysed both in MYMV infected and non-infected plants and the results are given in table () and figures (). It was observed that the chlorophyll content was less in the infected plant compared to healthy plants which might be due to virus manipulation on the genomic expression of the plants and it affects the formation of plastids in young growing leaves and it is line with earlier report by Sinha and Srivastava, (2010). Similar reports were obtained by many workers where chlorophyll content was affected in many host plants due to virus infection (Pandey and Joshi 1989; Rathore and Agnihotri, 1995; Thind et al., 1996, Dantre et al., 1996; Sutha and Rajappan, 1998; Mali et al., 2000, Gill and Singh, 2000, Milavec et al., 2001; Funayama-Noguchi and Terashima 2006, Pineda et al., 2008, Arora et al. 2009 and Singh and Shukla, 2009). This is a kind of host manipulation by virus for spread where the loss of chlorophyll followed development of yellowing in host plants would also influence the host selection behaviour of the vector (Fig).

The phenol content had changed with virus infection where it was higher in infected plant compared to non-infected plants (Fig) and this might be due to the plant response to virus infection where the defense system of the plant would have been activated due to the virus infection which in turn affected the fitness and survival of the vector. It is very interesting to mention here the B.tabaci is not surviving or reproducing on greengram host but it behaviour has been specifically manipulated by the virus for spread. The presence of total phenols, ortho dihydroxy phenols, tannins and gossypol are having significant negative impact on reproductive success of whitefly adults (Rao and Panwar, 2001; Perveen et al., 2001; Raghuraman et al., 2004; Halder and Srinivasan, 2007).

The total protein content was increased in virus infected mungbean plants than healthy plants (Fig.). This might be due to increased nitrogen uptake and respiration for amino acid synthesis in infected plants (Szczepanski and Redolfi, 1985; Shivaprasad et al., 2005; Hofius et al., 2001). There is a possibility that the elevated aminoacids or specific proteins would have some positive relationship with the endosymbionts associated in the midgut of whitfly adult which favour the virus transmission.

The total sugars content was more in healthy leaves compared to infected leaves (Fig) and this might be reason for attraction or preference of viruliferous whitfly to non-infected plants at the early stage of plant growth (seedling stage) and after the host manipulation by the virus, the preference of whitefly shifted where the non-viruliferous whitefly prefer infected plant for further spread of the virus. During virus infection, abnormal amount of protein production needed for protein synthesis for rapid synthesis of virus particle resulted in faster breakdown of carbon compounds towards amino acid synthesis creates decreased production of carbohydrates level of plant leaves. The findings are in line with earlier works (Ashraf and Zafar, 2000; Goncalves et al., 2005; Handford and Carr, 2007; Adomako and Hutcheon, 2008; Goodman et al., 2008; Singh and Shukla, 2009).

The peroxidase and polyphenol oxidese are defense enzyme exist in the plant. The present study showed that these enzymes are increased in MYMV infected plants than healthy plants (Fig. & Fig.). Enhancement of peroxidase and polyphenol oxidase are responsible for many physiological processes like oxidation of secondary metabolites ie, phenol that are toxic to invading microorganisms and their increased activity might be due to the induced resistance to MYMV infection. Similar, reports were found on increased level of PPO and PO activities in infected leaves of resistant cultivar were higher than in susceptible (Tripathi et al. 1975; Stahman and Demorest, 1973; Kaur et al., 1991; Sohal and Bajaj, 1993; Jagdish Chandra and Tyagi, 1993) In contrast Sohal and Bajaj (1993) reported that the specific activities of PPO and PO decreased MYMV infected leaves compared to susceptible mungbean cultivars.

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Evaluation of Coffee Hybrid Varieties Against Major Coffee Insect Pests at Teppi, Southwestern, Ethiopia

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Abstract:
Coffee, originated in Ethiopia is utilized in a number of ways. It is grown in more than 50 countries around the world. With cultivation, marketing, export and processing of the crop a million of people depends on for livelihood. Insect pest is the major challenge of coffee production in Ethiopia. The insect pest evaluation of coffee hybrid variety trial was under taken during the year 2013 (2005 E.C) for the objective evaluation of coffee hybrid variety trial for insect pest tolerant at Teppi, Southwestern Ethiopia. From the evaluation, we understand that there is a correlation between insect pest attack, canopy width and number of primary branches. The other all vegetative parameters had no relationship with insect pest occurrence. Geisha is highly infected with Coffee blotch leaf minor. Geisha was susceptible to coffee serpentine leaf minor in addition to coffee blotch leaf minor. For the next coffee hybridization study the following hybrid parents were not suitable for insect tolerance: HC-1, HC-3, HC-4, HC-5, HC-7 and HC-13. For the future study, in addition to morphological parameters, the biochemical content of the leaf responsible for insect pest attraction need attention.

Keywords: Hybrid, insect pests, vegetative parameters, Teppi

INTRODUCTION

Ethiopia is the main producer of coffee in the African continent, and the fifth largest exporter of Arabica coffee globally (International Coffee Organization, 2019). Coffee is the backbone of the Ethiopian economy, accounting for 70% of the foreign exchange earnings and 10% of the government revenue while employing 25% of the domestic labor force (Yilma *et al.*, 1999). Four coffee production systems are used in Ethiopia: coffee gardens tended by smallholder farmers near their residences (70%), semi-forest and forest coffee (25%), and modern plantations (5%) (Woldemariam *et al.*, 2008).

Smallholder producers account for 95% of production, while state-owned plantations and investor plantations account for 4.4% and 0.6% of production, respectively (FDRE, 2003).Arabica coffee originated in Ethiopia, and only grows in its wild form in Ethiopia, Uganda, and Kenya (Koebler *et al.*, 2013). The top coffee-producing districts in Ethiopia are Oromia, South Nations, Nationalities, and Peoples Regional State (James *et al.*, 2015). The major constraints to coffee production in Ethiopia include diseases, insect pests, a lack of access to market information, lack of physical infrastructure, poor extension services, limited farm management, low soil fertility, and changes in climatic conditions (Tadesse *et al.*, 2020).

Ethiopian originated coffee (*Coffea arabica* L.) production is challenged by different insect pests in its home of origin. Efforts were made by researchers to increase the productivity and production of coffee (World Coffee Research, 2022). The two species of coffee with economic importance are the Robusta coffee (*Coffea canephora* Pierre) and Arabica coffee (*Coffea arabica* Linnaeus). Arabica coffee has relatively higher demand (over 70% of the world coffee market)

due to its higher beverage quality (Vegro *et al*., 2020). The incidence and spread of pests and disease are also likely to increase and affect crop yields and quality (Jaramillo, 2011). Thirteen arthropod pests and five non-arthropod vertebrate pest species were found to depend on coffee regardless of the landrace type at Gedeo zone (Fekadu *et al*., 2016).

In Africa, as elsewhere, coffee farmers are continuously threatened by a range of pest and disease problems. Many of these are minor in terms of the damage they cause and their effect on yield and quality. However, some, such as coffee berry disease, coffee leaf rust and coffee wilt disease (*tracheomycosis*), can be very serious indeed and can have a major impact not only on individual farmers but on the economy of countries or regions heavily dependent on coffee for foreign exchange earnings (Mike A. Rutherford and Noah Phiri, 2006).

Timor hybrid: this is a naturally occurring hybrid from the island of Timor in Southeast Asia. This is a cross between the local Arabica and Robusta varieties, and has been widely cultivated due to its resistance to coffee leaf rust. Jember: this coffee was developed by Indian breeders in the 1940's and was introduced to Indonesian farmers, which is where it tends to be grown to this day. It is named after the Jember Indonesian coffee and cacao research institute who first introduced it as a commercial plant. F1 hybrids: these are new hybrid coffees that researchers have been developing in labs over the last few years in an attempt to cultivate varieties that are asdisease resistant as possible, while still tasting amazing (Specialty Coffee Association, 2021). Ascoffee rust resistance genes are dominant, when hybrids are derived from a cross between a rust- resistant Catimor parent and an Ethiopian accession, they will have the same level of resistanceas the Catimor parent (Bertrand *et al*., 2011). There is high chance to exploit host plant resistancefor the management of coffee berry borer in Ethiopia (Chemeda Abedeta Garbaba and Weyessa Garedew, 2019).

Resistant coffee plants have been obtained through the transfer of resistance genes from *C. racemosa* to the susceptible *C. arabica* cultivars (Guerreiro-Filho, 2006). However, homogeneous and stable populations, sexually propagated, have not been obtained yet, suggesting that resistance inheritance is more complex than the control by two dominant and complementary genes (Guerreiro-Filho *et al*., 1999).

Thus, the cloning of resistant coffee plants with desirable agronomic traits may represent a viable alternative to be explored by different methods of vegetative propagation, such as the cutting of orthotropic branches, or the somatic embryogenesis through in vitro culture of leaf tissue (Bertrand *et al*., 2011). Basic knowledge about the biology of this insect, the damage it causes to the plants, the identification of sources of resistance, the development of efficient selection methods and knowledge about the genetics of resistance have contributed to the efficiency of the ongoing genetic improvement programs. Recently, coffee genomics studies have also promoted an improvement in the efficiency of the development of cultivars resistant to this insect (Ramiro DA *et al*., 2006).

Researchers will evaluate and select the best-performing crosses, focusing on key traits of interest identified by local breeders and experts. Priority targets include: Disease and Insect resistance/tolerance, Productivity, Traits linked to climate resilience (e.g., yield stability), Traits linked to harvest (e.g., uniform ripening time), and Traits linked to production efficiency (e.g., dwarf/tall) and Tolerance to abiotic stresses (drought, heat) (World Coffee Research, 2022). So

the objective of this study is to evaluate coffee hybrid varieties for insect pest tolerance at Teppi, Southwestern, Ethiopia.

MATERIALS AND METHODS

Description of the Study Area

Teppi is located at Southwestern parts of Ethiopia at 35°08'E longitude and 7°08'N latitude and at an altitude of 1200 m.a.s.l. It is situated at 600km from the capital city (Addis Ababa) of Ethiopia. The average annual rain fall of the area is 1630mm and the mean minimum and maximum temperature of the area are 15°c and 30°c, respectively.

Materials and Design Used for the Study

Fifteen coffee promising hybrids were used for the study with already released coffee hybrid checks Ababuna and Geisha. The design used was RCBD with three replications.

Methods Used for the Study

Three coffee trees were taken per plot for each insect and each coffee tree branches were taken from the upper, middle and bottom to record the insect pest attack on each branches leaf. From the upper, middle and bottom branches, three representative branches were taken and all the leaves were counted. From the total leaf counted, infected leaves with insect pests were recorded.Sixteen coffee trees per plot with two rows were used for the study.

Morphological and Insect Pest Data's Taken

About six morphological parameters were taken for the evaluation of coffee morphological parameters with insect pest attack. The six morphological parameters taken for the evaluations are Height, no of nodes, no of primary branch, Height up to the first primary branch, Girth and Canopy width. The insect pests' data taken were coffee blotch leaf minor, coffee serpentine leaf minor and coffee leaf skeletonize.

Data Analysis

Finally, the collected data and information from the experiments were recorded, tabulated and subjected to the analysis using an appropriate computer software program, the SAS® Statistical Analysis Software (Release 9.4 for Windows). The Fishers protected Least Significant Difference (LSD) values were used ($P<0.05$) to separate means of different treatments.

RESULTS

Table 1. Effect of Coffee canopy density to the attack of insect pests

Plot No.	Variety	No. of primary branches			mean	Canopy width in cm			mean
		Replication				Replication			
		I	II	III		I	II	III	
1	HC-1	61.8	60.8	69	63.9	1.56	1.61	1.63	1.6
2	HC-2	56.8	82.4	86.4	75.2	1.536	1.54	1.82	1.63
3	HC-3	55.8	65.8	73.4	65	1.648	1.72	1.56	1.64
4	HC-4	61	62.6	90	71.2	1.7	1.8	1.74	1.75
5	HC-5	67.2	68.8	74.2	70.1	1.82	1.95	1.76	1.84
6	HC-6	62.2	50.6	72.2	61.7	1.562	1.67	1.7	1.64
7	HC-7	72	69.8	80	73.9	1.81	1.68	1.68	1.72
8	HC-8	60.4	67	69	65.5	1.65	1.56	1.7	1.64

9	HC-9	69.2	61.8	92.6	74.5	1.86	1.78	1.79	1.81
10	HC-10	57.6	81.8	74.8	71.4	1.66	1.65	1.68	1.66
11	HC-11	49.8	75.2	93	72.7	1.58	1.62	1.61	1.6
12	HC-12	50.4	48.8	82.8	60.7	1.76	1.64	1.67	1.69
13	HC-13	62.4	79.2	75.8	72.5	1.8	1.57	1.49	1.62
14	HC-14	59.6	71.6	80.6	70.6	1.76	1.48	1.63	1.62
15	HC-15	52.8	74.8	76.4	68	1.7	1.6	1.72	1.67
16	Ababuna(C_1)	42.6	50	64	52.2	1.74	1.7	1.68	1.71
17	Geisha(C_2)	60.6	74.6	75.6	70.3	1.46	1.52	1.34	1.44

Source: Wakjira Getachew, 2005 E.C

Table 2. Effect of different Coffee morphological parameters to the attack of insect pests

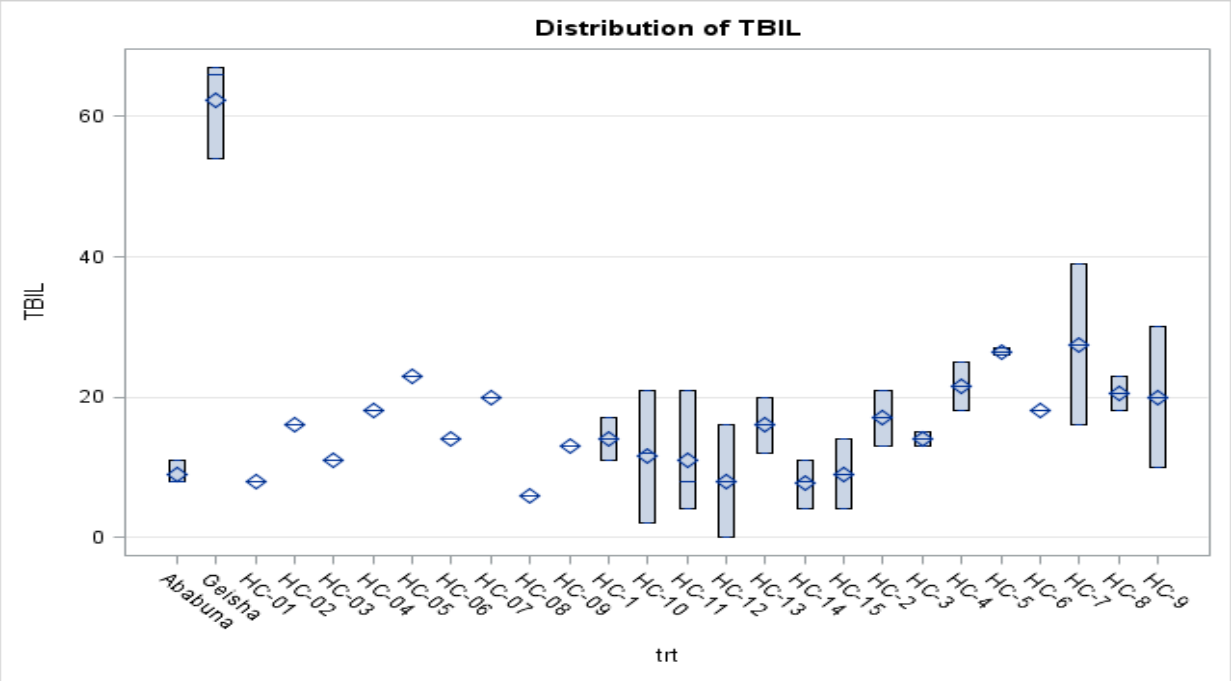
Plot No.	Variety	Height in cm			mean	No. of nodes/tree			mean	Height up to first primary branches			mean	Girth in cm			mean
		Replication				**Replication**				**Replication**				**Replication**			
		I	II	III		I	II	III		I	II	III		I	II	III	
1	HC-1	259	293	295	282	33.6	51	33.4	39.3	33.6	37	34	34.9	2.92	2.94	2.88	2.91
2	HC-2	278	344	356	326	36.6	32.6	40.6	36.6	35	30.2	35.2	33.5	3.5	3.32	2.98	3.27
3	HC-3	283	294	294	290	37.4	32.6	33.4	34.5	34.4	34	34	34.1	3.36	3.04	2.68	3.03
4	HC-4	294	323	376	331	38.8	35	42	38.6	34.2	37	39.6	36.9	3.78	3.54	3.6	3.64
5	HC-5	313	320	331	321	45	51.4	35.2	43.9	38.2	35.4	37.2	36.9	3.54	3.44	2.96	3.31
6	HC-6	305	287	340	311	46.6	47.4	36	43.3	34	33.8	32.6	33.5	2.74	2.86	2.78	2.79
7	HC-7	372	344	298	338	60.2	32.4	36.8	43.1	40.4	37	42	39.8	3.78	3.9	3.48	3.72
8	HC-8	302	310	320	311	37	30.4	34.2	33.9	27.6	29	28.6	28.4	3.16	3.24	2.7	3.03
9	HC-9	316	305	367	329	42.6	50.4	42.2	45.1	39.6	38.6	38	38.7	3.3	3.6	3.22	3.37
10	HC-10	346	351	363	353	45	37.4	39	40.5	37.8	41	37.8	38.9	3.18	3.04	2.8	3.01
11	HC-11	304	356	380	347	43.4	41.6	44.6	43.2	33.8	35	39.4	36.1	3	3.46	2.9	3.12
12	HC-12	304	310	331	315	44.8	50	39.4	44.7	34	36.8	43	37.9	3.06	2.86	2.9	2.94
13	HC-13	303	333	285	307	44.4	37.8	35.6	39.3	30.4	29	35.8	31.7	3.1	3.2	2.56	2.95
14	HC-14	350	316	358	341	52.2	35.4	39	42.2	36.2	36	39	37.1	4.42	2.84	3.14	3.47
15	HC-15	335	358	332	342	46.8	32.4	37.6	38.9	35.4	39	37.8	37.4	3.2	3.26	2.92	3.13
16	Ababuna(C_1)	288	318	328	311	40.2	43.4	33.2	38.9	33.6	39.8	38	37.1	2.86	2.96	3	2.94
17	Geisha(C_2)	226	252	276	251	45.8	32.6	37.4	38.6	23.4	25	29.4	25.9	2.64	3.04	2.6	2.76

Source: Wakjira Getachew, 2005 E.C

Table 3. Evaluation of coffee hybrid variety trial for blotch leaf minor at Teppi

Coffee blotch leaf minor						
Plot	Trt	R1	R2	R3	Total	Rank
1	HC-01	8	11	17	36	11
2	HC-02	16	21	13	50	7
3	HC-03	11	13	15	39	10
4	HC-04	18	18	25	61	4
5	HC-05	23	26	27	76	2
6	HC-06	14	18	18	50	7
7	HC-07	20	16	39	75	3
8	HC-08	6	18	23	47	9
9	HC-09	13	10	30	53	5
10	HC-10	21	2	12	35	12
11	HC-11	21	4	8	33	13
12	HC-12	8	16	0	24	15
13	HC-13	20	16	12	48	8
14	HC-14	11	4	8	23	16
15	HC-15	9	4	14	27	14
16	Ababuna	8	8	11	27	14
17	Geisha	66	67	54	187	1

Source: Wakjira Getachew, 2005 E.C

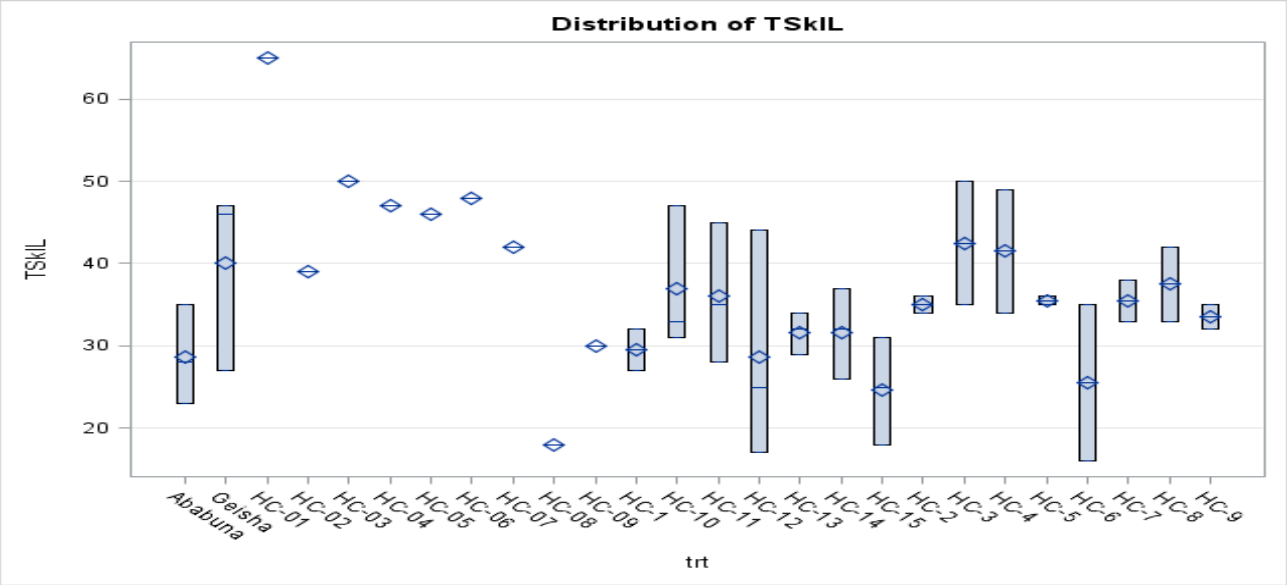


TBIL= Total blotch infected leaf

Table 4. Evaluation of coffee hybrid variety trial for Leaf Skeletonizer at Teppi

Coffee leaf skeletonizer						
Plot	Trt	R1	R2	R3	Total	Rank
1	HC-01	65	32	27	**124**	**3**
2	HC-02	39	34	36	**109**	**8**
3	HC-03	50	50	35	**135**	**1**
4	HC-04	47	49	34	**130**	**2**
5	HC-05	46	35	36	**117**	**5**
6	HC-06	48	35	16	**99**	**10**
7	HC-07	42	38	33	**113**	**6**
8	HC-08	18	42	33	**93**	**13**
9	HC-09	30	35	32	**97**	**11**
10	HC-10	47	31	33	**111**	**7**
11	HC-11	35	45	28	**108**	**9**
12	HC-12	25	44	17	**86**	**14**
13	HC-13	29	32	34	**95**	**12**
14	HC-14	32	26	37	**95**	**12**
15	HC-15	18	31	25	**74**	**15**
16	Ababuna	35	28	23	**86**	**14**
17	Geisha	47	46	27	**120**	**4**

Source: Wakjira Getachew, 2005 E.C

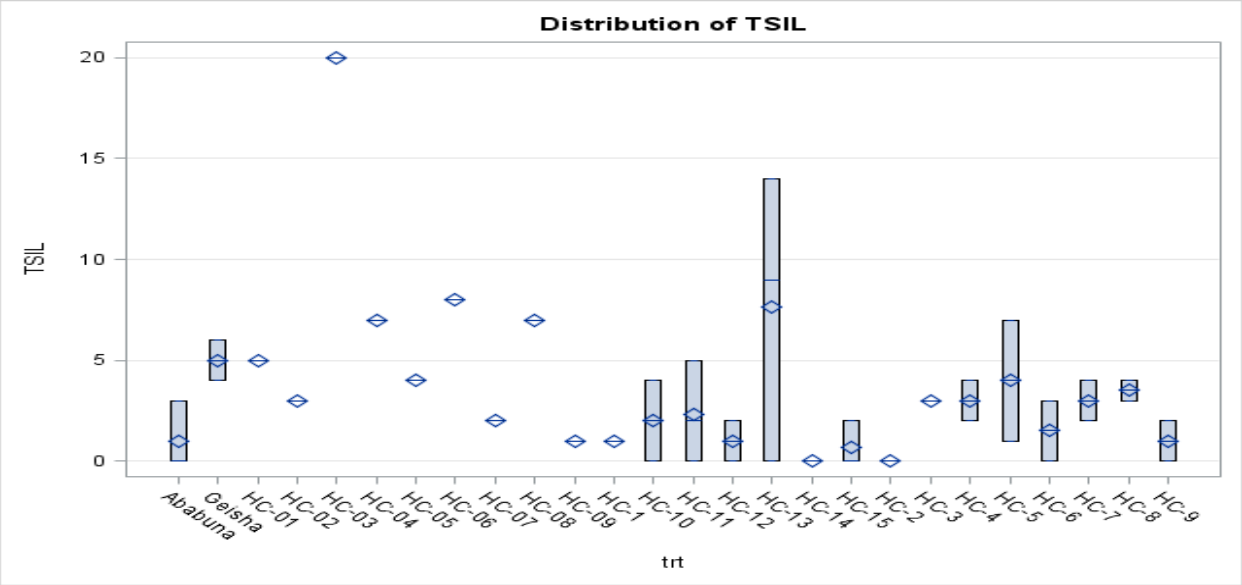


TSkIL=Total skeletonizer infected leaf

Table 5. Evaluation of coffee hybrid variety trial for Serpentine Leaf Minor at Teppi

Coffee serpentine leaf minor						
Plot	Trt	R1	R2	R3	Total	Rank
1	HC-01	5	1	1	7	**9**
2	HC-02	3	0	0	3	**11**
3	HC-03	20	3	3	26	**1**
4	HC-04	7	4	2	13	**5**
5	HC-05	4	1	7	12	**6**
6	HC-06	8	0	3	11	**7**
7	HC-07	2	2	4	8	**8**
8	HC-08	7	4	3	14	**4**
9	HC-09	1	2	0	3	**11**
10	HC-10	0	2	4	6	**10**
11	HC-11	5	2	0	7	**9**
12	HC-12	0	2	1	3	**11**
13	HC-13	9	14	0	23	**2**
14	HC-14	0	0	0	0	**13**
15	HC-15	0	0	2	2	**12**
16	Ababuna	0	3	0	3	**11**
17	Geisha	5	6	4	15	**3**

Source: Wakjira Getachew, 2005 E.C



TSIL=Total serpentine infected leaf

DISCUSSIONS

From the above result, two vegetative parameters: canopy width and no of primary branches were related with insect pest infestation. The highest the number of primary branch and the more compact, it's affected by insect pests. Insect pest infestation has no relationship with the other parameters. For the evaluation of coffee blotch leaf minor Geisha is the first coffee variety attacked with this insect pest and also in line with specialty coffee association, 2021 Geisha coffee is susceptible to leaf rust. Different types and degrees of resistance illustrate the relationship between the coffee plant and the leaf miner. The great variation in the growth of lesions due to coffee leaf miners in leaves of the species *C. racemosa, C. setenophylla, C. kapakata*, among others (Guerreiro-Filho *et al.*, 1991), is probably due to phytochemicals that interfere in the normal development of the caterpillars and it is a clear example of antibiosis (Ramiro DA *et al.*, 2006). HC-5 and HC-7 are the second and the third respectively. For the evaluation of coffee leaf skeletonizes HC-3 is the first attacked by this insect. HC-4 and HC-1 are the second and the third respectively. For the evaluation of coffee serpentine leaf minor HC-3is the first attacked by this insect. HC-13 and Geisha are the second and the third respectively.

CONCLUSIONS

To increase the yield of coffee with hybridization, insect pest and disease tolerance quality of the coffee must take attention for sustainable coffee yield increment. More compact coffee variety had more insects to hide. Geisha coffee was seriously attacked by blotch leaf minor from all the treatments. The leaf of Geisha coffee is broad and deep green. According to Mercon Specialty, 2019, the best way to prevent pests is through good farm management. Choice of variety, shade management, selective pesticide use, and plant nutrition management are important considerations.

RECOMMENDATIONS

Therefore, the coffee tree must be pruned regularly for more air circulation to reduce insect pest attack on coffee. The coffee leaf content and insect pest attack relation of Geisha coffee variety need great attentionin the future to study. HC-3 was susceptible to coffee leaf skeletonizes and coffee serpentine leaf minor from all the treatments used for the study and needs care in the future of coffee variety development for coffee insect pest tolerance.

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Review on Potential of Liming for Sustainable Management Some Selected Soil Chemical Properties and Crop Yield Improved in Tropical Soil

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Abstract:
Acid soils of the tropical soil were greatly responsive to applications of lime fertilizer. Successive applications of lime drastically decreased exchangeable aluminum to the minimum level, and raised soil pH close to the optimum pH requirement of many cereals. Other alternative materials include silicates of calcium or calcium and magnesium, wood ash and several industrial by-products such as slag that can produce modest amounts of other nutrients such as phosphorus and calcium. In order to produce a better crop yield on acid soils, farmers are recommended to apply alkaline materials such as lime (primarily calcium carbonate) to increase the soil pH and thus eliminate Al toxicity, and to apply P fertilizer to increase the bioavailable P in soil. The usual agricultural practice for most crops is to maintain a soil pH of 6.0-6.5 by the addition of lime, applied as calcium carbonate calcium hydroxide or calcium oxide. Traditionally, methods used to raise soil pH include; use of mulch from agro-forestry tree species, burning of sites to give ash and use of animal wastes although such materials are not available in the right amounts desired and, in most cases, they are too bulky. However, in many developing countries, where semi subsistence agriculture prevails, the lack and/or high cost of lime prevent its use. Under such conditions, alternative means of managing soil acidity need to be developed. Research has shown that additions of green manures, FYM, and composts to acid soils can reduce Al toxicity and increase crop yields. So, government should either subsidize the lime or encourage more investors to produce lime in order to decrease the lime cost. The farmers' practice like applying farmyard manure, compost and other organic wastes in backyard which can add organic matter to the soil should be appreciated and encouraged.

Keywords: lime, soil pH, organic matter, alkaline material, soil exchangeable acidity, basic cation

INTRODUCTION

Over half of the world population currently lives in regions dominated by acid soils (Yang *et al*., 2004) whose productivity is on the decline to meet the food requirements of the ever-increasing population, especially in the tropics (Hartemink, 2002). Soil acidity is a major yield-limiting factor for crop production worldwide. The land area affected by acidity is estimated at 4 billion hectares, representing approximately 30 % of the total ice-free land area of the world (Sumner and Noble, 2003).

In Ethiopia, heavy population pressure has resulted in practically all cultivatable land being farmed, eliminating expansion of cropped area as the main driver of agricultural growth, which had been the case in the 1990s (World Bank, 2007). In the tropics, substantial weathering of soils over millennia has resulted in the leaching of crop nutrient bases (mainly K, Mg and Ca). This is followed by replacement by H, Al and Mn cations that contribute to acid related stresses on crop

production (Okalebo *et al*., 2009). Acid soils are phytotoxic as a result of nutritional disorders, deficiencies, or unavailability of essential nutrients such as calcium, magnesium, molybdenum, and phosphorus, and toxicity of aluminum, manganese, and hydrogen activity (Foy, 1984). The solubility of soil compounds and, therefore, nutrient availability to plants is related to soil pH Acid infertility factors limit crop growth and yield as well as soil productivity in highly weathered soils of humid and sub-humid regions of the world due to deficiency of essential nutrient elements (Akinrinade *et al*., 2006). Likewise, feeding the ever-increasing human population is most challenging in developing countries because of soil degradation. For instance, in Sub-Saharan African countries, soil fertility depletion is the fundamental biophysical cause for declining per capita food production (Sanchez *et al*., 1997). This challenge will continue as population pressure increases and degradation of soil resources is aggravated.

According to Angaw and Desta (1988), soil acidity severely affects the yields of many crops in the western, south-western and southern parts of high rainfall areas of Ethiopia. The infertility of soils in these areas is attributed to excessive concentration of aluminum (Al), iron (Fe) or manganese (Mn) on one hand; and to deficiencies of calcium (Ca), magnesium (Mg), phosphorus (P) and molybdenum (Mo) on the other (Mesfin, 1996). Soil acidity is a major constraint to maize (*Zea mays)* production on tropical soils due to toxic levels of aluminium (Al) and the concomitant phosphorus (P) deficiency that hinder plant growth (Kisinyo *et al.,* 2005). To increase crop yields and reduce crop production risks associated with soil acidity, there is need to focus on soil amendment practices that target efficiency of nutrients use in soils especially phosphorus that is made unavailable chemically for plant uptake. Liming acid soils is general practice to reduce aluminum toxicity and is considered to many scientists as the first step towards providing a balanced nutrition for cultivated plants (Essington, 2004).

Thus, low soil pH is considered to be the main cause of yield reduction for all crops in general and acid sensitive crops in particular in tropical soil. Liming improves acid soils' physical, chemical and biological properties and increases plant production. Numerous authors (Havlin *et al*., 1999; Hughes *et al*., 2004; Loncaric *et al*., 2007) reported that liming of acid soils increased crop yield and caused significant changes in soil properties modifying soil acidity and nutrient availability. Soil acidity is now a serious threat to crop production in most high land of tropical soil. Currently, it is estimated that about 40.9% of the total arable land of Ethiopia is affected by soil acidity (Taye Bekele, 2007) which covers 95% of the cropped area and contain almost 85% of the Ethiopian population.

This implies that effort has to be made to improve the fertility and productivity of the acidic and infertile soils of highlands Ethiopia areas and make sure that optimum utilization of same is made to secure the well-beings of the present and future generations. Therefore, the objective of this pepper was to review on potential of liming for sustainable management of some selected soil chemical properties and crop yields in tropical soil.

SOIL ACIDITY IN TROPICS

Soil acidity is a serious agricultural and environmental problem that limits the growth of pasture and crops in many parts of the world including Latin America, North America, Asia, Africa, Europe and Australia (Baligar *et al*., 1993). Vast areas of tropical lands that were once fertile have been rendered unproductive due to continuous cultivation and erosion which has caused physical soil degradation, loss of soil organic matter and a decrease in Cation exchange capacity (CEC) as well as increased Al and Mn toxicity (Mba, 2006). In high rainfall areas of Ethiopia, soil acidity is a

severe problem and can lead to decline or complete failure of crop production (Angaw and Desta, 1988). The extent of acidity and mining of soil fertility is believed to increase from year to year due to anthropogenic (man-made) activity. This fact and the peculiarity of tropical soils described above imply that in the tropics, it is wiser to focus on lime application for the correction of Al toxicity instead of trying to bring the soil pH close to neutral. This is why this document focuses on the decrease or suppression of the Al toxicity.

Among biological properties, activities of beneficial microorganisms are adversely affected by soil acidity, which has profound effects on the decomposition of organic matter, nutrient mineralization, and immobilization, uptake and utilization by plants, and consequently on crop yields (Fageria and Baligar, 2008). Although soil acidity is a serious problem in the western and southwestern parts of Ethiopia, no in-depth studies are found on the causes and the extent of acidity. Another important difference between soils from temperate and tropical regions is the nature of soil surface charge. The most common source of surface charge on soil colloids is from structural imperfections in the crystal structure. As a result, its exact extent is difficult to ascertain, but available information indicates that about 40.9% of the Ethiopian total land area is affected by soil acidity. Of this land area, about 27.7% is moderately acidic (pH in KCl) 4.5 -5.5) and about 13.2% is strongly (pH in KCl) < 4.5) acidic (Schlede, 1989). Soil acidity can decrease crop yield, seedling emergence and survival, establishment and persistence, legume nodulation and root growth (Marschner, 2002). In addition, deficiencies of essential nutrient elements such as Ca, Mg, P and Mo may also be involved (Somani, 1996). In the tropics the soil acidity is aggravated by leaching or/and continuous removal of basic cations through crop harvest (Wassie H andShiferaw B 2014). Integrated application of lime and fertilizer gave the highest yield only when NPK and full rate of lime are applied (Wassie H andShiferaw B 2014). If lime application sought to bring significantly appreciable improvement in the yield of crops it has to be with applied balanced application of NPK is a must (Wassie H andShiferaw B 2011).

CAUSES OF SOIL ACIDITY

Soil acidification is a complex set of processes resulting in the formation of an acid soil. The summation of different anthropogenic and natural processes including leaching of exchangeable bases, basic cation uptake by plants, decomposition of organic materials, application of commercial fertilizers and other farming practices produce acid soil (Brady and Weil, 2002). The causes of soil acidity are more easily understood when we consider that a soil is acid when there is an abundance of acidic cations, like hydrogen (H^+) and aluminum (Al^{+++}) present compared to the alkaline cations like calcium (Ca^{++}), magnesium (Mg++), potassium (K^+), and sodium (Na^+) (Johnson, 1914). Acidification of the soil is a slow natural process and part of normal weathering. Many farming activities cause an increase in the rate of acidification of the soil. Changes in soil pHCa under agricultural use are measured in tens or hundreds of years rather than thousands of years as in the natural environment.

Most acidic soils, however, have been developed as a result of leaching losses and crop removal of bases (Somania, 1996). In Ethiopia, soil acidity increase involves climatic factors such as rainfall, temperature, topographic factors and morphological factors (Mesfin, 1998). Even plant growth will contribute to acidification; a major nutrient uptake process is to exchange hydrogen ions at the root surface for needed base ions such as calcium, magnesium, and potassium (Marschner, 2002). In conditions where rainfall exceeds evapotranspiration (leaching) during most of the year, the basic soil cations (Ca, Mg, K) are gradually depleted and replaced with cations held in colloidal soil reserves, leading to soil acidity. Soil acidity is really a high rainfall problem (Slattery and

Hollier, 2002). Once the anions are removed from the soil, the normal neutralization process by oxidation of carboxylate compounds to carbon dioxide and water cannot occur, resulting in long-term acidification of soils (Bohn *et al.*, 2001). In the effects of human activity, when acidifying fertilizers particularly, ammonium sulfate and mono-ammonium phosphate (MAP) are added to soil, nitrification occurs and causes soil acidity (Somani, 1996). Decaying organic matter produces H^+ which is responsible for acidity. The carbon dioxide (CO_2) produced by decaying organic matter reacts with water in the soil to form a weak acid called carbonic acid. This is the same acid that develops when CO_2 in the atmosphere reacts with rain to form acid rain naturally. Like rainfall, the contribution to acid soil development by decaying organic matter is generally very small, and it would only be the accumulated effects of many years that might ever be measured in a field (Slatter and Hollier, 2002).

EFFECTS OF LIME ON CHEMICAL PROPERTIES OF ACID SOILS

Soil Reaction (pH) and Its Management

Soil reaction is one of the most important physiological characteristics of the soil solution. It affects nutrient availability and toxicity, microbial activity, and root growth. Soil reaction is expressed in terms of pH indicating whether the soil is acidic, alkaline or neutral. Human activity can change the pH of a soil too; the addition of most nitrogen fertilizers and organic nutrient sources (compost and manure) leads to formation of nitric acid (HNO_3) and/or sulfuric acid (H_2SO_4). Both are strong acids that cause an increase in soil acidity (i.e., a decrease the pH of the soil). Solubility of many essential elements for plants and nutrient uptake rates are pH dependant. Generally, anions like nitrate and phosphate are taken up at a faster rate under slightly acid conditions whereas the cation uptake rates seem to be faster around the more neutral pH range (Rorison, 1980). It could be attributed to reduction of Al_3^+ ions concentration in soil solution and in exchangeable sites because of lime and manure application (Pearce and Sumner, 1997). Wong and Swift, (2003) in their findings also reported that addition of organic manures to acid soils increased soil pH, decreased Al saturation, and thereby improved conditions for plant growth.

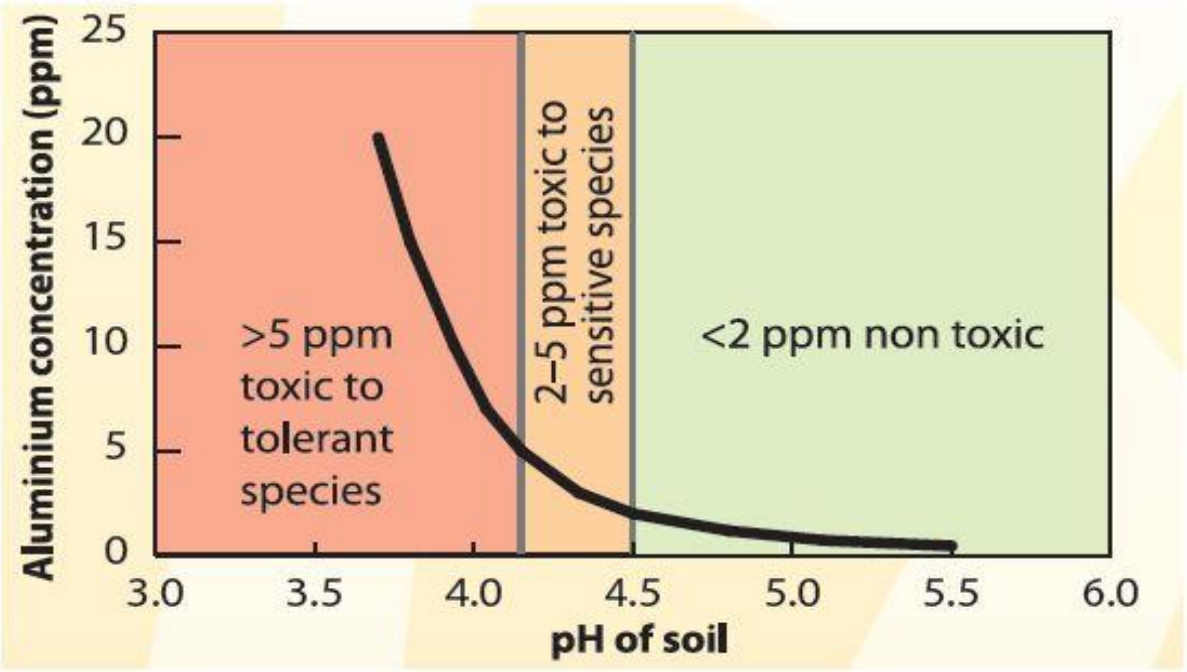

Figure 1. Effects of aluminum concentration on soil pH.
Source: https://www.agric.wa.gov.au/soil-acidity/effects-soil-acidity

Available Phosphorus

Acid soils, present mostly in humid tropical and subtropical areas of the world, are characterized by having excess H^+, Mn^{2+}, and $A1^{3+}$, with deficiencies of Ca^{2+}, Mg^{2+}, and $PO4^{3-}$. Additionally, sulfur dioxide and other air pollutants cause acid soil stress in areas other than the tropics (Foy, 1984). Total phosphorus (P) gives an indication of the total reserve of the nutrient in the soil. However, it is a poor indicator of the availability level since most of the soil P may be fixed. Phosphorus deficiency problems are compounded by widespread high phosphorus fixation capacity of acid soils (Somani, 1996). Soluble aluminium immobilises phosphorus in the soil and the plant, causing symptoms of phosphorus deficiency, that is, small and dark-green or occasionally purple leaves. The symptoms become more pronounced as the aluminium level increases. Lime can be used to improve the availability of native and/or added P by increasing soil pH because mineral oxide binding of P decreases as the pH increases from 4–7 (Haynes 1982). Rapid increases in available P following the reaction of added lime to desorb fixed P have been termed the *P spring effect* (Mike and Nanthi 2003). The increase in the agronomic yields and P uptake of wheat due to lime and wood ash may be attributed to the increases in soil pH, reduction in the toxicity of Al^{3+} and Mn^{2+} and reduction in nutrient deficiency (Ca, P or Mo) as well as due to indirect effect of better physical condition of the soil (Haynes,1984). Wood ash was more effective than lime in increasing the dry shoot biomass and the P uptake of the wheat (Asmare.M, *et al*,.2015). Magdoff et al. (1984) also evaluated land application of wood ash and limestone in a greenhouse and laboratory research project. Two soils were mixed with wood ash; limestone and a lime stone-wood ash mix (90:10). Plant growth, nutrient uptake, and soil chemical changes were measured during the growth of maize. Ash gave better response than limestone. The effect of over-liming was reduced when ash was added with the limestone.

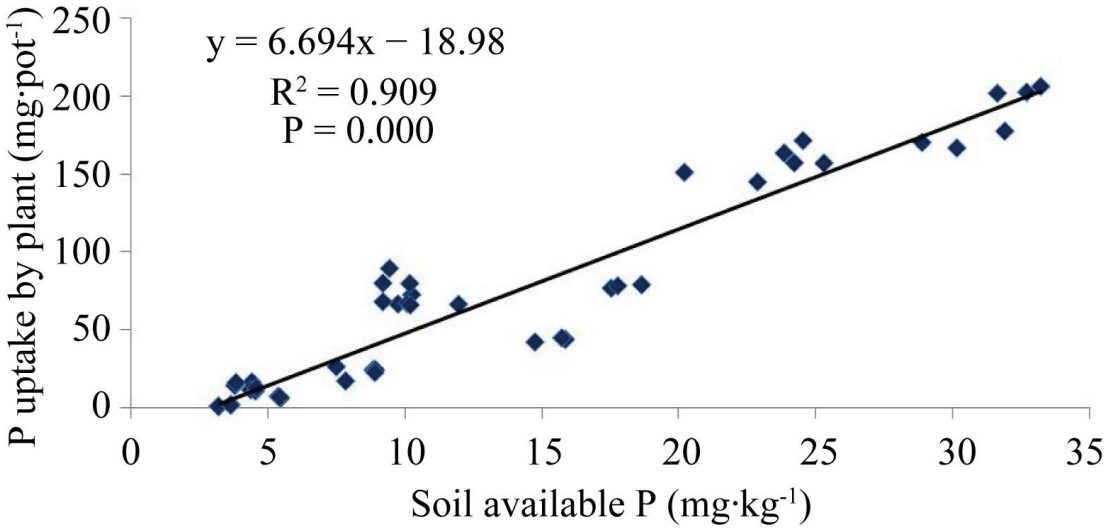

Figure 2. Correlations of available P with P uptake by In- dian spinach

Source: Ashoka S, *et al* 2014

Exchangeable Acidity

Exchangeable acidity consists of any mono-meric aluminum or iron, as well as any exchangeable H that may be present in the exchange sites (Bohn *et al*., 2001). Exchangeable acidity in soils is almost entirely due to mono-meric Al^{3+} ions (Thomas and Hargrove, 1984). This is because only Al^{3+} is a common exchangeable cation in moderately to strongly acidic soils (Bohn *et al*., 2001). Liming with the highest rate (3750 kg $CaCO_3$ ha-1) recorded the minimum value of exchangeable acidity and exchangeable almunium which reduced them to 0.36 cmol (+) Kg-1 and 0.24 cmol (+)

kg-1 respectively (Adane B.2014). This decrease may be ascribed to the increased replacement of Al by Ca in the exchange site and by the subsequent precipitation of Al as Al $(OH)_3$, as the soil was limed. Soil exchangeable acidity is the total amount of the Cation Exchange Capacity (CEC) of a soil that is due to H^+ and Al^{3+} ions (FAO, 1995). It indicates soil disturbances due to high Al concentrations (which are toxic to plants and soil organisms). Exchangeable acidity is measured only if the pH value drops under 7 because only then does the concentration of exchangeable H+ and Al^{3+} ions become significant.

Cation Exchangeable Capacity

The cation exchange capacity (CEC) of a soil represents the total quantity of negative charge available to attract cations in the soil solution. It is one of the most important chemical properties of soils as it strongly influences nutrient availability (Havlin *et al*., 1999). Numerically the mean values of soils exchangeable Ca^{2+} ion and CEC of each land use type showed increments with the increase of applied lime rates and soil pH. High CEC values are usually associated with humus compared to those exhibited by the inorganic clays, especially kaolinite and Fe, Al oxides (Brady and Weil, 2002). The increase in CEC due to liming could be attributed to the change in pH and the release of the initially blocked is omorphous and interlayer substitional negative charge by deprotonation of the variable charge minerals and functional groups of humic compounds caused by Ca^{2+}. The greater amount of negative charge available on the surfaces of these minerals results in the increase in CEC (Pionke HB, Corey RB 1967). The colloids of highly weathered soils have a constant surface potential, which is mainly a characteristic of kaolinite, Al-interlayerd chlorites, hydrous-oxides of Fe and Al, and Alorganic matter complexes (Gillman and Bell, 1978). As result, the CEC of highly weathered soils is pH dependant, and it is a function of the constituent minerals and organic matter. Under such soil, the CEC is increased as the pH of the soil increased by liming. This is because not only the permanent charge but also the pH dependant charge is operative when the pH is adjusted to a value higher than the point of zero charge (PZC) with buffered salt solutions (Mesfin, 1996). Liming acidic soils indirectly increases the effective cation exchange capacity (ECEC) of soils that contain organic matter or variably charged clay minerals (Bohn *et al*., 2001). Thomas and Hargrove (1984) found that the ECEC of acidic soils increased slowly at pH values of around 5.0 but increased very rapidly at pH 8.0. Haynes and Ludecke (1981) reported that the influence of lime addition on CEC was not consistent although increased P addition generally increased measured CEC values. However, the CEC determined after maize harvest in western Ethiopia (Alemayehu, 1999) and six weeks incubation periods in Nigeria (Adetunji and Bamiro, 1994) showed a sharp increase due to application of lime. These effects of lime and P addition in increasing the ECEC of the soil might have been caused by the increase in the exchangeable basic cation (particularly Ca, Mg and K) contents of the soil. Similarly, Thomas and Hargrove (1984) also found very rapid increase in ECEC of acidic soils as the pH of the soil increased by liming. However, the direct relationships between pH, exchangeable Ca and CEC with the increase of the lime rates is attributed to the applied lime which enhances the concentration of Ca^{2+} and thereby increases the soil pH due to the dissociation of agricultural lime and replacement of H^+ and Al^{3+} from the soil solution and soil exchange complex.

IMPACT OF SOIL ACIDITY TO ROOT DEVELOPMENT AND SOIL MICROORGANISMS

Soil microbiological properties can serve as soil quality indicators because soil microorganisms are the second most important (after plants) biological agents in the agricultural ecosystem (Fageria, 2002). Soil microorganisms provide the primary driving force for many chemical and biochemical processes and thus affect nutrient cycling, soil fertility, and carbon cycling (He et al., 2003). Acid soils affect plants in several ways. For instance, Al prevents plant root

elongation due to its direct effect on metabolism or indirectly by rendering the phosphate in the soil unavailable by binding it to form aluminium phosphates thereby leading to overall low crop yields (Mora et al., 2005). Plant species and varieties differ, in their sensitivity to the conditions in acid soils (Wild, 1993). Toxic levels of aluminum harm the crop by "root pruning." that is, a small amount of aluminum in the soil solution in excess of what is normal causes the roots of most plants to either deteriorate or stop growing. As a result, the plants are unable to absorb water and nutrients normally and will appear stunted and exhibit nutrient deficiency symptoms, especially those for phosphorus. The final effect is either complete crop failure or significant yield loss. Maize lies in the medium tolerance range and would do well in the 5.5-6.0 pH range. Acidity produces complex interactions of plant growth-limiting factors involving physical, chemical, and biological properties of soil. Among biological properties, activities of beneficial microorganisms are adversely affected by soil acidity, which has profound effects on the decomposition of organic matter, nutrient mineralization, and immobilization, uptake and utilization by plants, and consequently on crop yields (Huber, 2006). Soil microorganisms especially bacteria and fungi have been shown to be sensitive to organic amendments and lime application (Magdoff, 2001). Organic amendments are known to increase the abundance of various components of the soil food web, including the soil fungal and bacterial communities (Forge et al., 2008 The availability of Phosphorus for plant uptake can therefore be increased by treatment with mineral acids, organic acids, and a mixture of organic materials, biological treatment, etc. Incorporating organic manures and P materials has been shown to enhance the solubility (Sharif et al., 2011).

PROBLEMS OF PLANT NUTRITION IN ACID SOILS

The effects of soil acidity, acidification, and liming can be classified into three main categories that cannot always be sharply distinguished: the availability of nutrients and toxic elements, biological activity, and soil structure. The first category will be treated here. The availability of essential plant nutrients is affected by soil pH. In acid soils, there are problems of both plant nutrient deficiencies and toxicities of three elements (Al, Mn, and H) (Baragengana, R.1990). Water is essential for plant life as soil solution because it carries all plant nutrients through mass flow and/or diffusion to the roots. N, after hydrogen and oxygen, is the element needed in greatest quantity from the soil for plant growth. Plants absorb most N in the nitrate (NO_{3-}) form, but they also absorb N in the ammonium form (NH_4^+). The latter is preferentially absorbed at high pH (Adams, 1984). Nitrate-N can be more available than ammonium-N, because NO_{3-}-N is mobile in soils and can move to plant roots with soil water, since it is negatively charged. Ammonium-N, on the other hand, is relatively immobile, being attracted to negatively charged surfaces of the soil's CEC. The optimum range of oxidation of NH_4^+ nitrogen to NO_3^- is between pH 5 and 8. In acid soils below pH 5, nitrification is severely reduced. The result is that N in the soil becomes less available to plants. At soil pH <5, both nitrification and mineralization (conversion of N from organic molecules into inorganic forms by microbial activity) are diminished, making N less available to plants. Liming of soils of pH less than 5 results in increased heterotrophic microbial activity, resulting in greater availability of mineral forms of N (NH_4^+ and NO_3^-) for uptake by plants.

EFFECTS OF LIME ON PLANT YIELD IMPROVEMENT IN TROPICAL SOIL

Tolerance to Al toxicity or acidic soils differs greatly among cereal species, and barley is usually considered the most susceptible member of the Poaceae (Garvin and Carver, 2003). Aluminium causes extensive root injury, leading to poor ion and water uptake (Barcelo & Poschenrieder, 2002). The acidic soils are naturally deficient in total and plant available phosphorus. This is because significant portions of applied P are immobilized due to precipitation of P as insoluble Al

phosphate. The liming of acidic soils results in the release of P for plant uptake; this effect is often referred to as "P spring effect" of lime (Bolan *et al.*, 2003). Root tips have been found to be the primary site of aluminum injury, and the distal part of the transition zone has been identified as the target site in maize (Zea mays) (Sivaguru& Horst, 1998). The Al tolerance order as reported is maize> rye> triticale> wheat> barley (Polle and Konzak, 1985), rye> oats> millet> bread wheat> barley> durum wheat (Bona et al., 1993). Aluminum is known to induce a decrease in mitotic activity in many plants, and the aluminum-induced reduction in the number of proliferating cells is accompanied by the shortening of the region of cell division in maize (Panda, 2007). Plant growth improvement in acid soil is not due to addition of basic cations (Ca, Mg), but it is due to increasing pH that reduces toxicity of phytotoxic levels of Al (Fageria and Beligar, 2008). Past laboratory and field studies conducted to determine how phosphorus availability responds to lime addition reported that liming enhances P uptake by alleviating Al toxicity and thereby improving root growth (Haynes, 1982). Wood ash was more effective than lime in increasing the dry shoot biomass and the P uptake of the wheat, (Asmare M. et al,.2015). Shiferaw B. 2014 reported highest barley grain and biomass yields were obtained from applications of full lime rate + NPK in.

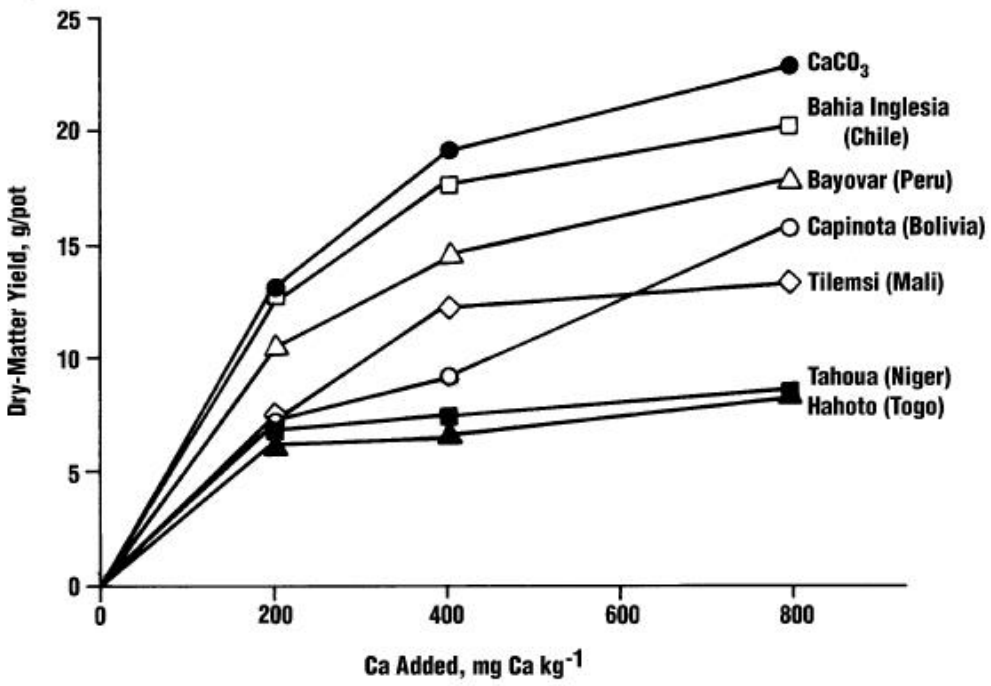

Fig.3. Maize dry matter yield response to PR source and $Caco_3$ ultisols

Source: Hellunss. D.T *et al.*,1989

MANAGEMENT OPTION OF SOIL ACIDITY PROBLEMS

Liming as Soil Acid Management Strategy

In order to produce a better crop yield on acid soils, farmers are recommended to apply alkaline materials such as lime (primarily calcium carbonate) to increase the soil pH and thus eliminate Al toxicity, and to apply P fertilizer to increase the bioavailable P in soil. Many studies report the beneficial Ca effects in different crops growing in acid soils (Mora *et al.*, 2002). According to Sanchez *et al.*, (1997), soil fertility reduction on the smallholder farms remains the central cause of decline in per capita food production in Africa, a situation that threatens food security. The rising rural poverty and the price fluctuations on fertilizer and other farm inputs has led to decline in capacity of farmers in Sub-Saharan Africa to put through necessary fertility measures

(Borlaugh, 2003). The modern agriculture production requires the implementation of efficient, sustainable, and environmentally sound management practices (Fageria and Baligar, 2008). Traditional methods of managing acidic soils for agriculture in the humid tropics, such as slash-and-burn agriculture practiced in its various forms, also rely on the "application" of carbonates in this case in the form of ashes produced by the burning of woody and vegetative materials (Juo and Manu, 1996). Ashe contains a large proportion of the carbonates of mineral cations (K, Ca, &Mg) originally present in the vegetation. In this context, liming is an important practice to achieve optimum yields of all crops grown on acid soils. Adequate liming eliminates soil acidity and toxicity of Al, Mn, and H; improves soil structure (aeration); improves availabilities of Ca, P, Mo, and Mg, and N_2 fixation; and reduces the availabilities of Mn, Zn, Cu, and Fe and leaching loss of cations. For several crops, liming results in some chemical changes in the soil such as, increase in pH, effective cation exchange capacity (ECEC), and exchangeable Ca, decrease in toxic elements for example Al^{3+} and Mn^{2+} and changes in the proportion of basic cations in CEC sites (Ezekiel, 2006). Lime requirement refers to the amount of lime required to neutralize all or part of the acidity in soil (both solution and reserve) from an initial level to a desired or target less acid condition. The target level of soil acidity depends both on the soil and the crop. The crop affects the LR through its level of tolerance to acid soil conditions. Lime also makes phosphorus that is added to the soil to be more available for plant growth and increases the availability of nitrogen by hastening the decomposition of organic matter (Donald, 2011**).** Lime is usually added to acid soils to increase soil pH. Its addition not only replaces hydrogen ions and raises soil pH, thereby eliminating most major problems associated with acid soils but it also provides two nutrients, calcium, and magnesium to the soil. Over-liming, however, can significantly reduce the bioavailability of micronutrients (Zn, Cu, Fe, Mn and B), which decrease with increasing pH (Fageria *et al.*, 2002).

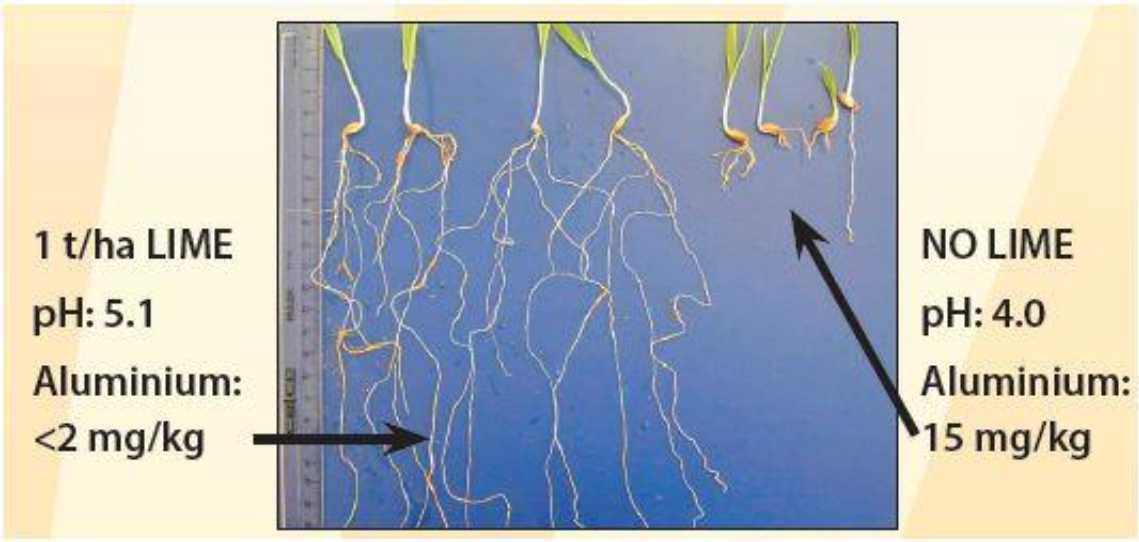

Fig.4: Effects of limed and unlimed on plant roots
Source: https://www.agric.wa.gov.au/soil-acidity/effects-soil-acidity

Traditional methods of managing acidic soils for agriculture in the humid tropics, such as slash-and-burn agriculture practiced in its various forms, also rely on the "application" of carbonates in this case in the form of ashes produced by the burning of woody and vegetative materials (Juo and Manu, 1996). Ashe contains a large proportion of the carbonates of mineral cations (K, Ca, &Mg) originally present in the vegetation. Liming is a practice largely used to neutralize the acidity of the surface soil layers, but does not seem to be

effective in acidity amelioration at a subsoil level (Carvalho and van Raig, 1997). Allmaras *et al.* (1987) evaluated lime and gypsum treatment on a wheat-peas culture rotation and measured the propagated density of *Fusarium solani ssp. pisi* in the 0 to 15 cm soil layer. They found a decrease in the density of propagation (37%) of this fungus species by effect of lime, meanwhile between 15 to 45 cm of depth soil gypsum reduced its propagation density in 22%, therefore concluded that Ca can improve the resistance of the membrane in pea-root to attack by *Fusarium* pathogens, or allowing greater microbial antagonism.

Quality of Lime:

Lime quality is an important consideration. The most effective liming products are those that have a high neutralising value (i.e., greater than 80%) and a small particle size. Lime is a good investment to maintain the soil pH as well as soil health and to maintain production and profitability. Millar *et al.* (1958) who reported that, fineness through various treatments (calcination, crushing, sieving) of limestone, increases the solubility of limes. The amount of particle sizes and their efficiency factors affect fineness factor of limes which could compromise its effectiveness with time. Halvin *et al*. (2005) reported that the efficiency factor of one (for lime with smaller particles < 0.2mm) is an indication of high solubility (degradability) and efficiency of lime in changing soil properties.

Fineness:

Liming resources are valued for their capacity to ameliorate soil acidity and to maintain the availability of calcium and magnesium for crops. There are a number of liming materials and each liming material has a specific composition and capacity to neutralize acidity. There are two benefits to fineness. The finer particles in a liming material react more quickly in the soil as they have a greater surface area to react with acids. Secondly, they will be better distributed through the soil after incorporation. There is a compromise between fineness and the cost of production, so there are practical limits on fineness (Brett *et al*., 2005). The quality of the materials depends on their mineralogy, purity, and on the size of the particles (Heckman 2000). The standard for measuring purity is calcium carbonate equivalence (CCE) (Spies and Harms, 2004) so that the CCE value for pure calcium carbonate is 100 % (Whitney and Lamond, 1993). Along with other inputs, acid soils can be ameliorated with lime to make them highly productive on sustainable bases. In this connection, the good news is that there are vast lime resources within Ethiopia and these can be systematically exploited (Schlede, 1989). The degree of fineness is equally important in the selection of a liming material since the speed with which the various materials will react is dependent on the surface area that is in contact with the soil. On the other hand, limestone is entirely a different matter since its reaction is related to particle size (Taye Bekele, 2008). The fineness of liming materials is important because the surface area usually affects dissolution rate (Whitney and Lamond 1993). Small particles dissolve quickly and so decrease soil acidity quickly, whereas coarse particles may react very slowly and are of reduced value in managing soil acidity (Spies and Harms 2004).

Comparing Liming Materials Information:

These include calcite ($CaCO_3$), burnt lime (CaO), slaked lime ($Ca(OH)_2$), dolomite ($CaMg(CO_3)_2$) and slag ($CaSiO_3$). On the label will allow a comparison of the particle sizes and the neutralising value of liming products. A spreadsheet has been developed by some of the limestone crushers to assist in comparing liming products using this data. The acid neutralizing value of liming materials is expressed in terms of calcium carbonate equivalent (CCE), defined as the acid neutralizing capacity of a liming material expressed as a weight percentage of pure CaCO3.

A comparative evaluation of lime, gypsum and PG demonstrated that lime treatment ($CaCO_3$ 2500 kg ha-1) increased exchangeable Ca and decreased exchangeable Al in the 0-5 cm soil layer, but no significant changes were observed below 5 cm, which suggested limited lime leaching **(**Meriño-Gergichevich *et al*., 2010**).**

Applying and Incorporating Lime:

For the quickest and maximum effect, limestone should be finely crushed, evenly spread and incorporated into the soil to 10 cm (Brett U et al,.2005). Pavan *et al*. (1984) reported that gypsum was more effective in lowering Al concentration within the 100 cm depth profile, while lime effects were observed only in the upper 20 cm. Caires *et al*. (2006) showed that gypsum ameliorate subsoil pH and Al-toxicity, increasing Ca and S level in wheat leaves.

Because limestone moves very slowly down through the soil, incorporation should be to the depth of the acidity problem (or as deep as practicable) for the most effective and speedy response. his means that deeper plowing would be necessary for through blending with the soil (Taye bekele, 2008). However, the deep lime incorporation requires the implementation of specific equipment and results in higher costs, which makes it unfeasible for use by small farm (Carvalho and van Raig, 1997).

Effect of Organic Matter Application on Soil Acidity Management Strategy

Soil organic matter maintenance and management are central to the sustainability of soil fertility in the tropics (Womer *et al*., 1994). It has been perceived for a long time that animal manure lowers soil pH as some commercial nitrogen fertilizers do (Hailin, 1998). Organic matter has been found to increase the soil's ability to hold and make available essential plant nutrients and to resist the natural tendency of soils to become acidic (Reis and Rodella, 2002). Working on a long-term field and greenhouse studies using animal manure as an ameliorating agent on acid and neutral soils, Hailin (1998) found that soil pH was higher by 0.5 units to a depth of 2 feet under littered soils than in un-littered soils. Soil organic matter increases the soil flora and fauna (associated with the soil aggregation, improved infiltration of water, and reduced soil erosion), complex toxic Al^{3+} and Mn^{2+} ions (leading to better rooting), increases the buffering capacity of low activity clay soils, and increases water holding capacity (Woomer *et al.*, 1994). Although the use of liming materials is the most effective way of managing and correcting soil acidity, numerous studies reviewed by Wong and Swift (2003) have shown that the application of organic matter such as compost, manure, and un decomposed plant residues can ameliorate the effect of soil acidity on crop growth. The main reason why manure raises soil pH is due to the presence of calcium and magnesium elements in it and its buffer capacity because of forming complexes with Al and Fe in acid soils (Tang *et al.,* 2007). As such, applying manure to acid soils not only supplies the much-needed nutrients and organic colloids for plant growth but also reduces soil acidity, thus improving phosphorus availability and reduces aluminium toxicity (Hailin, 1998). Returning organic amendments in form of livestock manures and crop residues to soil could be important in supplying crop nutrients as well as improving soil moisture conditions and increasing availability of P by stimulating microorganisms that solubilize soil P (Fankem *et al.,* 2008). However, organic amendment in the longer term as they decompose, have an acidifying effect on soils. Nevertheless, for farmers who do not have access to agricultural liming materials either because of they are unavailable or too costly, these materials may be useful as a partial short-term solution to soil acidity.

Use of Plant Tolerant to Soil Acidity

Cultivated crops vary in their tolerance to soil acidity. Therefore, selecting and growing species and variety adaptable to acidic soils is one solution n (Scott *et a., 1997*). Acidity in the surface soil can be corrected by applying agricultural lime. When the subsoil layers are acidic, amelioration of the surface layer will not allow the plant roots to penetrate the acid layer and reach critical water and nutrient supplies below it. Selection and development of genotypes with enhanced tolerance to acid soils and toxic levels of Al is the only reasonable solution to this problem. For chromosome manipulation in wheat and triticale breeding, it is important to know which wheat and rye chromosomes carry genes for aluminum tolerance (Aniol and Gustafson, 1984).

For example, recent research indicates the existence of genes for Al tolerance in plants and bacteria such as rhizobia (Eshetu Lemma 2011). Furthermore, alternative means to chelate Al to reduce its toxic effect in the rhizosphere of plants would be the selection of crop or pasture cultivars excreting organic acids, such as citrate, gluconate, malate or oxalate. Such resistance has been further described in wheat where the root apices are the target site of Al toxicity (Conyers *et al.,* 2005). The use of tolerant plants is important where sub soil acidity exists; particularly as the amelioration of acidity in the subsoil (i.e., below the volume where the lime has been incorporated) after liming is slow (Coventry *et al*., 1997). The choice of species /variety with better yield potential is obviously important for economic reasons (Eshetu Lemma 2011). However, the choice of species or variety is also an important as a management strategy to offset acidification, as plant s tolerant to soil acidity are more likely to be using water through a better root growth and be reaching more NO_3^- deeper in the soil profile (Eshetu Lemma 2011).

CONCLUSION

Low soil pH is considered to be the main cause of yield reduction for all crops in general and acid sensitive crops in particular in tropical soil. Liming improves acid soils' physical, chemical and biological properties and increases plant production. Numerous authors (Havlin *et al*., 1999; Hughes *et al*., 2004; Loncaric *et al*., 2007) reported that liming of acid soils increased crop yield and caused significant changes in soil properties modifying soil acidity and nutrient availability. Soil acidity is now a serious threat to crop production in most high land of tropical soil. Major constraints to crop production in acid soils are toxicities of Al and Mn and deficiencies of Ca/Mg (Jackson, 1967). In order to produce a better crop yield on acid soils, farmers are recommended to apply alkaline materials such as lime (primarily calcium carbonate) to increase the soil pH and thus eliminate Al toxicity, and to apply P fertilizer to increase the bioavailable P in soil. Lime requirement refers to the amount of lime required to neutralize all or part of the acidity in soil (both solution and reserve) from an initial level to a desired or target less acid condition. The target level of soil acidity depends both on the soil and the crop. The acidic soils are naturally deficient in total and plant available phosphorus. This is because significant portions of applied P are immobilized due to precipitation of P as insoluble Al phosphate. The liming of acidic soils results in the release of P for plant uptake; this effect is often referred to as ''P spring effect'' of lime (Bolan *et al.,* 2003). Acid soils can be managed in two ways, i.e., either by growing suitable crops for a particular soil pH or by ameliorating the soils through application of amendments, which counteract the soil acidity (Biswas and Mukherjee, 1994). However, in many developing countries, where semi subsistence agriculture prevails, the lack and/or high cost of lime prevent its use. Under such conditions, alternative means of managing soil acidity need to be developed. Research has shown that additions of green manures, FYM, and composts to acid soils can reduce Al toxicity and increase crop yields (Tejada *et al.,* (2006).

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Does Rice Farmers Respond to Changing Climate: Empirical Evidence from Ebonyi State, Nigeria

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Abstract:
The study examined does rice farmers respond to changing climate; empirical evidence from Ebonyi State, Nigeria. Multi-stage sampling was used to select 70 rice farmers who were administered with a questionnaire. The study made use of primary data and were analyzed using descriptive statistics. Results showed that the rice farmers were in their productive age, 52 years, more of females, 67.1%, married 58.8%, relatively educated 11.4% and have household size of 7 persons and 16 years of farming experience. Majority of the rice farmers 70%, had high perception and awareness of climate change relative to 17.1% and 12.9% who had low and moderate perceptions. In response to climate change, rice farmers engaged the following; planting improved rice varieties 100%, Insurance 9%, planting of multiple/different crops 80%, livelihood diversification 44.3%, soil and water conservation techniques 84.3% and adjusting planting and harvesting dates 94.3%. Rice farmers also encountered challenges such as pests and disease attacks 85.7%, high cost of inputs materials 100%, unfavorable price fluctuations 64.3% and unavailability of improved rice varieties 80%. Farmers should be encouraged to seek early climate change information and practice more of climate smart practices to mitigate negative destructive effects of climate change on rice production.

Keywords: Rice Cultivation, Farmers, Responses, Changing Climate, Constraints, Ebonyi State

INTRODUCTION

Climate change has become a global phenomenon and of much concern to crop producers all over the world. The Intergovernmental Panel on Climate Change (IPCC, 2020) opined climate change as a fluctuation between normally experienced climate conditions (rainfall, temperature, wind, etc) and a different but recurrent set of climate conditions over a given region of the world. It is brought about by the increase in emission of greenhouse gases (GHGs) in the atmosphere that destabilize the ozone layer, leading to global warming (IPCC, 2018). It is further characterized in the concentration of the greenhouse gases (GHGs) trapped in the atmosphere as a result of human induced activities such as fossil fuel combustion, deforestation, and industrial processing, etc (IPCC, 2018). Other contributors include agricultural activities such as overgrazing of farmlands, continuous cropping, burning of forests and use of organic fertilizers which triggers GHG concentration (IPCC, 2020). Thus, a slight change in the climate will consequentially affect the status of agricultural production of an area (Adeagbo et al., 2021). Climate change is reported to have influenced agricultural production globally with rising food deficits, high food imports, low crop yield, poor income and heightened poverty levels amongst food crop farmers across the

world (Agovino et al., 2019). Thus, higher temperatures affect production of crops such as rice, maize, millet alongside encouraging weed and pest proliferation. Studies by the International Food Policy Research Institute (IFPRI, 2020), shows that increased floods and droughts increase the likelihood of short-run crop failures and long-run production declines in both crops and animals. Howbeit, the predominance of rain-fed agriculture, the scarcity of capital for climate adaptation measures, the warmer baseline climates and heightened exposure to extreme weather events in Africa makes agriculture more vulnerable to climate change. Food crop is particularly sensitive to climate change because crop yield depends largely on prevailing climate conditions specifically temperature and rainfall patterns (Ahsan et al., 2020).

Rice production is both a victim and a contributor to climate change. Rice cultivation is responsible for about 10 percent of global greenhouse gas emissions from agriculture (FAO, 2022). Rice one of the most abundant crops grown and consumed globally, makes up 12% of global methane emissions – and a staggering 1.5% of total greenhouse gas emissions (FAO, 2019). Rice is the nutritious staple crop for more than half of the world's people, but growing rice produces methane, a greenhouse gas more than 30 times as potent as carbon dioxide (FAO, 2020). Rice is a principal food crop grown in Nigeria despite facing a lot of climate change effects. It engages many producers, processors, and marketers at various stages but not without some climate related challenges (Kumar et al., 2021). It is a staple food which constitutes a major part of the diet of many countries in the world (FAO, 2021). It is widely produced in South-East Asia, the United States of America and other European countries. In Ebonyi State, the importance of rice over other crops, in terms of its production and the number of consumers that depend solely on it as their daily staple food is changing due to incidence of climate change. Rice production in the State is heavily affected by extreme weather and climate factors such as increased rainfall, relative humidity, wind variation, flood and extreme temperatures and is expected to get worse with further intensification of climate change as documented by Onyeneke et al. (2021). These climatic variables affect the bio-physical quality of the soil, and the speed of soil depletion on apparently well nurished soil causing low yield, and reduction in rice production in the state, this has equally affected the income and earnings of the rice producers increasing their poverty level and reducing their economic livelihood. The above incidences have created a wide gap in knowledge which this study seeks to fill in by examining the response strategies of rice farmers to changing climate in the state.

MATERIALS AND METHODS

The study was conducted in Ikwo Local Government Area Ebonyi State, Nigeria. Ikwo being one of the Local Government Area in Ebonyi State is located within latitude: $6^{o}3^{l}11^{l}$N and longitude: $8^{o}9^{l}$ 46^{l}E. Ikwo Local Government Area is made up of twelve autonomous communities. It has a land mass of approximately 5,000 kilometers squared and shares boundaries with Izzi in the North, Ezza in the West, Cross River State in the South and Abakaliki in the East. The rainfall pattern is bimodal with peaks in July and September and ranges to 2500mm while temperature is at 30^{oc}. They indigenes are farmers' historically and cultivate the following in large quantities; Rice (Ereshi), Yam (Nji), Cocoyam (Nkashi) Cassava (Njakpu), Potatoes (Ogogo), Groundnut (Ashimoko), Soya bean (Azaku), Guinea corn (Igeri), Bambara nut (Akpanyinko) alongside with livestock production. Multistage sampling technique was used for sample selection. The first stage involved a random selection of four autonomous communities in Ikwo Local Government Area. The second stage progressed with another random selection of four villages from the selected communities giving a total of 16 villages. In the third stage, five rice farmers were randomly selected from the 16 villages making a total of 80 respondents for the study. The list of

rice farmers was provided by the Agriculture Development Programme Coordinators in the Local Government Area. Primary data was collected using the research instrument (questionnaire) which was administered in person through personal interview and focused group discussion. Out of the 80-questionnaire distributed, only 70 of them were found useful for data analysis. However, before actual data collection, the questionnaire was pre-tested using pilot survey to determine its reliability and content validity. Data were analyzed using descriptive statistics, such as the mean, frequency and percentages.

RESULTS AND DISCUSSION

Socio-economic Characteristics of the Rice Farmers

The socio-economic characteristics of the rice farmers are presented in Table 1. The table shows that majority of the farmers were within the age bracket of 51-60 years with a mean age of 52 years. This obviously implies that the farmers were advancing in age though still physically strong to carry out their farming operations. Increase in age engenders in-depth knowledge of agricultural operations which enhances improved farm output and income (Adeagbo et al., 2021). Majority of the rice farmers were females, 67.1% relative to the males, 32.9%. This implies that rice production was dominated by the female farmers in the state. This could be due to their over-involvement in rice farming relative to the male farmers who could be in engaged in non-agricultural occupations. Again, rice farming seems to be less strenuous hence the involvement of more women than the men (Agovino et al., 2019). Majority of the farmers were married, 58.8% and the singles, 7.1%. Also, about 11.4% were divorced and 22.9% widow/widower. This implies that marriage supports more of family labour used in rice production. This also shows that the married ones are more focused, dedicated and committed to their farming enterprise than the single farmers (Ahmad et al., 2020). About 22.9% of the farmers had primary education, 11.4% tertiary education, and 14.3% non-formal education. Thus, majority of the farmers 51.4% had secondary education; this implies that the rice farmers were relatively literate to understand farm production principles and techniques which are targeted towards improved rice production (Ahsan et al., 2020). The majority of the rice farmers, 74.2% had household size between 5-8 persons with a mean household size of 7 persons. This implies that the household size regarding the rice farmers was relatively large and could support their farming strength and production activities. A sizable household provides more of family labour relative to households with lesser household's sizes (FAO, 2022). Majority of the rice farmers, 92.8% were fully involved in farming operations and/ or activities while about 7.1% of them were engaged in farming activities and other related occupations. It should be noted here that these engaged occupations serve as sources of livelihoods and income earnings for farm families (FAO, 2020). Majority of the rice farmers had farm sizes within 0.1-1.0 hectares with a mean hectare of 0.7. This implies that the rice farmers cultivated less than 1 hectare of farmlands. This could be attributed to the scarcity of land in the area as well as land fragmentation which only accommodates small area of cultivation (FAO, 2019). About 18.6% of the rice farmers had between 3-4 physical contacts with extension agents, while majority of them 81.4% had between 1-2 physical contacts. The mean extension contacts were approximately 2 contacts, which implies that the rice farmers had low extension contacts with the extension agents, this could be ascribed to sometimes, the un-seriousness of the extension agents with their job responsibilities and/ or assignment given to them. Also, poor logistics could as well contribute to these anomalies (Igberi et al., 2022). The table shows that 11.4% of the farmers had no cooperative membership while a majority 88.6% belongs to rice cooperative societies. This implies that a majority of the rice farmers had access to information, farming inputs, credit facilities and others. Belonging to a cooperative group offers one the opportunity to relate and interact with other farmers across and within their territory and to

obtain certain useful information and agricultural inputs that would have been difficult to access individually (FAO, 2020). Majority of the rice farmers 77.1% participated in workshop/training between 3-4 times per cropping season. About 21.4% participated between 1-2 times. The mean participation value was 3.0 shows that on average the rice farmers participated at least 3 times per cropping year. Participation in these trainings and workshops instill new farming skills, knowledge acquisitions and adequate understanding of crop production principles which enhances better yield performances (Ikuemonisan et al., 2020). Majority of the rice farmers, 72.9% had farming experience between 11-20 years, with a mean farming experience of 16 years, implying that the rice farmers were well experienced in their farming operations and rice cultivation. Farming experience exposes the farmers to deeper knowledge and understanding of farm operations and production activities. This increases farm production and better farm performances in both the short and long run basis (Kogo et al., 2020). About 5.7% accessed their capital from banks, 18.6% from friends/relatives, 48.6% from personal savings, while 21.4% accessed their capital from co-operatives societies. The implication is that the rice farmers accessed their farm capital mostly via personal saving considering the fact that other sources may not be easily accessible as expected (FAO, 2019). About 4.3% got their land via pledge, 10.0%, got through purchase, 2.9%, got through gifts, 8.6% got through lease/rent and 74.3% via inheritance. This implies that the land acquisition in the area is majorly via inheritance as this source of land sometimes characterized the rural land ownerships (Kumar et al., 2021). Majority of the farmers, 71.4% utilized family labour, 17.1% made use of hired labourers while the remaining 11.4% used both family and hired labourers. This implies in general that the labour used in the area was mainly family labour relative to the hired labour, this could be probably due to the higher fares charged by hired labourers (Ahsan et al., 2020).

Socio-economic characteristics of the rice farmers

Age	**Frequency**	**Percentage**
20-30	09	12.9
31-40	16	22.9
41-50	10	14.3
51-60	35	50.0
Mean	**52**	
Sex		
Male	23	32.9
Female	47	67.1
Marital status		
Single	05	7.1
Married	41	58.8
Divorced	08	11.4
Level of education		
Primary	16	22.9
Secondary	36	51.4
Tertiary	08	11.4
Non formal	10	14.3
Household size		
1-4	15	21.4
5-8	52	74.2
9-12	03	4.3
13-16	-	
Mean	**7**	

Occupation		
Farming only	65	92.8
Farming and others	05	7.1
Farm Size		
0.1-1.0	54	77.1
1.1-2.0	12	17.1
2.1-3.0	2	2.9
3.1 & above	2	-
Mean	**0.7**	
Extension contacts		
1-2	57	81.4
3-4	13	18.6
5-6	-	-
7& above	-	-
Mean	**1.6**	
Cooperative membership		
Yes	62	88.6
No	08	11.4
Participation in workshop/training		
1-2	15	21.4
3-4	54	77.1
5-6	01	1.4
7 & above	-	-
Mean	**03**	
Farming Experience		
1-10	17	24.3
11-20	51	72.9
21-30	2	2.9
31-40	-	-
Mean	**16**	
Source of Capital		
Banks	04	5.7
Friends/relatives	13	18.6
personal savings	34	48.6
Co-operatives society	15	21.4
Other	04	5.7
Source of land		
Inheritance	52	74.3
Lease/rent	06	8.6
Gift	02	2.9
Purchase	07	10.0
Pledge	03	4.3
Source of labour used		
Family	50	71.4
Hired	12	17.1
Both	08	11.4

Source: Field survey data, 2023.

Perception of Rice Farmers to Climate Change

The perception of the rice farmers to climate change is presented in Table 2. The table shows that about 12.9% of the rice farmers had moderate perception of climate change; this implies that the rice farmers had reasonable knowledge about climate change probably via the radio, television, internets, and seminars/trainings (FAO, 2020). About 17.1% of the rice farmers had a low perception of climate change, this could be probably due to lack of information concerning climate change around these rice farmers in the area. This could also result from lack of interest on the part of the farmers on climate change related activities. Furthermore, the majority of the rice farmers, 70% had higher perception of climate change, this implies that these groups of farmers accessed climate change information and were more sensitive enough to the influence of climate change around their neighborhood and farm environments. This gives credence to the high perception and awareness of climate change perceived by the farmers Kumar et al. (2021).

Table 2: Perception of rice farmers to climate change

Climate Change Perception	Frequency	Percentage
High Perception	49	70.0
Low Perception	12	17.1
Moderate Perception	09	12.9
Total	**70**	**100**

Source: Field survey data, 2023.

Response of Rice Farmers to Climate Change

The response of the rice farmers to climate change is presented in Table 3. The table reveals that all the rice farmers, 100% responded to climate change by adopting planting improved rice varieties and erosion control measures. Improved rice varieties have shown to be effective in terms of yields, quality, and resistant to rice pests and diseases which attack rice crops both in the field and stored produce (Loum and Fogarassy, 2015). Opening up farm drainages, and creating path-ways for erosion and running water during and after rainfalls helps to check gully and soil erosion around farmlands. This measure prevents the farms from being flooded and from being washed away by rain-water. About 8.6% of the rice farmers responded through insurance. Insurance is overtly an important adaptation strategy engaged by modern day farmers to withstand the adverse effects of climate change and mitigate it accordingly (Mama et al., 2021). An insured farm averts certain farm risks and uncertainties inherent in agricultural production and at the same time instills peace of mind in the heart of the insurer. About 80.0% of the farmers responded via planting of multiple/different crops, 44.3% responded via livelihood diversification, 84.3% thorough soil and water conservation techniques, 94.3% via adjusting planting and harvesting dates and 60% via irrigation. Planting of different crop helps to mitigate and overcome negative influences of climate change (Onyeneke, 2021). The planting of multiple crops protects both the farmer and his/her farm lands from total crop failure occasioned by adverse climatic condition (Onyeneke et al., 2019). Livelihood diversification is noted to uplift the living standard of the poor rural farmers and provide maximum supports both for their families and farming enterprises in times of need and also during total crop failures. Thus, the farmers engage in other viable occupations outside farming. Soil and water conservation techniques secure the fertility of the farmland making them fertile at all times irrespective of the adverse climatic changes. This form of adaptation techniques is known to improve the soil structures, soil aeration, texture and moisture contents of the farmland leading to increased rice yield and output (Onyeneke, 2017). As climate change occurs frequently, rice farmers are forced to adjust their planting and harvesting dates to suit the prevailing climate conditions (Osuji et al., 2019). Adjusting planting

and harvesting dates ensures that farmers tailor their production to tally with the changing climate, this is necessary to negate the adverse consequences of climate change. Irrigation guards against shortage of water (low rainfall), prolonging dry season, unpredictable rainfall, late onset of rain, and early rain cessations (Onyeneke et al., 2019). The practice of irrigation averts total crop failures especially during prolonging dry seasons, ensuring that planted crops are well catered for even in the face of changing climate. Furthermore, 57.1% of the rice farmers responded via reliance on climate information and forecasts, 54.3% via collaboration with extension workers/agents, 95.7% via appropriate application of fertilizers, 72.9% via efficient and effective use of pesticide, and 32.9% via increased land access. Reliance on climate information and forecasts equip the farmers on how to go about their rice farming without encountering losses (Osuji et al., 2021). Collaboration with extension workers/agents helps the farmers in learning practical ways and methods in responding to climate change. Fertilizer applications increase the fertility of the soils especially on eroded and marginal farmland thus leading to improved rice yield. Adoption of pesticides use and application is seen as an integral response strategy used by most rice farmers to mitigate climate change effects. Increased land access enhances large scale cultivation and averts possible climatic destructions.

Table 3: Response of rice farmers to climate change

Response of Rice Farmers to Climate Change	*Frequency	Percentage
Planting improved rice varieties	70	100.0
Insurance	06	8.6
Planting of multiple/different crops	56	80.0
Livelihood diversification	31	44.3
Soil and water conservation techniques	59	84.3
Adjusting planting and harvesting dates	66	94.3
Irrigation	42	60.0
Reliance on climate information and forecasts	40	57.1
Collaboration with extension workers/agents	38	54.3
Appropriate application of fertilizer	67	95.7
Efficient and effective use of pesticide	51	72.9
Increased land access	23	32.9
Erosion control measures	70	100.0

Source: Field Survey data, 2023. *Multiple Responses

Constraints Encountered by Rice Farmers in Rice Production

The constraints encountered by rice farmers in rice production are presented in Table 4. The table shows that 100% of the rice farmer's indicated technical application of some adaptation (response) strategies, high cost of inputs materials and inadequate capital/severe poverty. No doubt some of the response strategies require technical applications which the farmers may not be conversant or in tune with it thus causing a little or no response to climate change effects (Woods et al., 2017). High cost of inputs materials has always been a serious problem in the input market as most rice farmers cannot afford to as much inputs as they need due to high cost. Inadequate capital/severe poverty also poses serious constraints in rice farming as majority of the rural farmers are poor and cannot procure enough capital to support their rice production (World Bank, 2020). About 95.7% of the rice farmers observed high cost of transportation, 72.9%, high cost and low availability of labor supply, 88.6%, inadequate farming lands, 80%, poor extension access and services and 84.3%, land fragmentation. High cost of transportation prevents most rice farmers from visiting their choice and desired markets to sell their rice produce making them

to result in farm-gate outright sales (Zamasiya et al., 2017). High cost and low availability of labor supply impede rice cultivation in that the available and limited man-labour inflates their labour fares making it extreme difficult for the poor farmers to cope, as they cannot afford the high labour charges per time. Inadequate farming lands distort large scale rice cultivation in that the issue of land scarcity prevents the farmers from both extensive and intensive farm cultivation (Zbigniew et al., 2017). Poor extension access and services causes low output of the farmers as the farmers are unable to access extension services which are targeted at improving the performance of the farmers per cropping season. In most cases, the extension agent fails to visit their places of primary assignments which are at the detriment of the rural rice farmers. Land fragmentation issues exist in most areas where there is scarcity of lands; the available ones are divided or shared in piecemeal to accommodate as much farmers as possible thus impeding land productivity of farmers. However, other perceived constraints encountered by rice farmers includes; problem of storage and processing facility, 91.4%, inadequate information concerning climate change, 92.9%, pests and disease attacks, 85.7%, Unfavorable price fluctuations, 64.3%, Unavailability of improved rice varieties 80%, weather and climate change issues, 70.3% and Infrastructural deficits which accounted for 61.4%. Problem of storage and processing facility encourages spoilage of stored rice and its value chain processes (Adeagbo et al., 2021). Inadequate information concerning climate change distorts or alters rice farmers farming calendar and exposes them to adverse climatic changes. Pests and disease attacks cripple planted rice seedlings causing serious havoc in rice cultivation and growth processes. Unfavorable price fluctuations negatively influence the income and revenue of rice farmers in general. Unavailability of improved rice varieties impedes rice cultivation as farmers' sticks to local rice seedlings which are easily susceptible to pests and diseases (Agovino et al., 2019). Weather and climate change issues poses lasting constraints in farm production as the era of changing climate is now being felt all over the world. High temperature impairs rice growth and production. Infrastructural deficits such as electricity, good pipe-borne water, hospitals and other basic amenities causes able bodied farmers to migrate to urban cities in search of white-collar jobs thereby leaving farming in the hands aged households and available youths who charges outrageous fares for labour supply (Osuji et al., 2019).

Table 4: Constraints encountered by rice farmers in rice production

Constraints Encountered by Rice Farmers	*Frequency	Percentage
High cost of transportation	67	95.7
High cost and low availability of labor supply	51	72.9
Technical application of some adaptation (response) strategies	70	100.0
Inadequate farming lands	62	88.6
Poor extension access and services	56	80.0
Land fragmentation	59	84.3
Problem of storage and processing facility	64	91.4
Inadequate capital/ Severe poverty	70	100.0
Inadequate information concerning climate change	65	92.9
Pests and disease attacks	60	85.7
High cost of inputs materials	70	100.0
Unfavorable price fluctuations	45	64.3
Unavailability of improved rice varieties	56	80.0
Weather and climate change issues	52	74.3
Infrastructural deficits	43	61.4

Source: Field Survey data, 2023. *Multiple Responses

CONCLUSION AND RECOMMENDATION

The findings of the study shows that the rice farmers were more of females, married, relatively educated and had household sizes of 7 persons and farming experience of 16 years. About 17.1% of the rice farmers had a low perception of climate change, while 70% and 13% had high and moderate perception of climate change. The study reveals that the rice farmers responded to climate change differently using various methods such as planting improved rice varieties, insurance, planting of multiple/different crops, livelihood diversification, soil and water conservation techniques, adjusting planting and harvesting dates and irrigation systems. Constraints faced by rice farmers includes; high cost of transportation, high cost and low availability of labor supply, technical application of some adaptation (response) strategies, inadequate farming lands, poor extension access and services, land fragmentation, problem of storage and processing facility, and inadequate capital/ severe poverty. Farmers should be encouraged to seek early climate change information and practice more of climate smart practices to mitigate negative destructive effects of climate change on rice production.

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Impact of Dredging the Okpoka River on Coastal Infrastructure: A Case Study of the Akpajo Bridge

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Abstract:
The Akpajo Bridge is deteriorating by the day and steadily awaiting eventual collapse due to extensive sand excavations in river beds proximal to the bridge. Sand mining has deepened the river channel, altered the hydrodynamics of the channel flow, increased river discharge beneath the bridge, accelerated shoreline erosion, scoured the piers thereby reducing the axial pile capacities supporting the bridge and ultimately compromising the safety of the bridge. Large scale sand mining from river beds is continuing on a scale never seen before in the Niger delta, due to the necessity of reclaiming land for development purposes and to meet construction needs in the region. Regulations are weak, monitoring of sand mining is non-existent. There is also a general lack of understanding of the risks to coastal infrastructure involved with sand mining in river beds. This paper investigates the threat to the stability and safety of the Akpajo bridge caused by the extensive mining of sand in the area. It establishes through computational analysis that a minimum distance of 94m (for sand river beds) from a bridge should be observed to guaranty the safety of bridge foundation. For clay riverbeds, slightly shorter minimum distances can be considered safe. The study further shows that the capacity of sand borrowing in river channels to generate bank instability is dependent on the composition and stratigraphy beneath the river bed.

INTRODUCTION

The excavation of sand from riverbeds is an age long practice in the Niger delta. It was initially considered sustainable when only artisanal miners were involved. The 1980s witnessed the involvement of large-scale operators who usually deploy a range of dredgers. The several potential adverse impacts of indiscriminate sand mining are well documented in literature (Bull and Scott, 1974; Collins et al.; 1990, Lake and Hinch, 1999; Padmalal et al 2008; Anooja et al 2011;). The most significant of these being: (a) bed degradation and consequent effects on channel and bank stability, (b) increased sediment loads, decreased water clarity and sedimentation; (c) changes in channel morphology and disturbance of ecologically important roughness elements in the river bed; (d) resuspension of contaminated sediment and release of contaminants with consequential ecological effects on bird nesting, fish migration, angling, etc. e) modification of the riparian zone including bank erosion; (f) direct destruction from heavy equipment operation; g) discharges from equipment and refueling; (h) Reduction in groundwater elevations; i) impacts on structures and access; (j) biosecurity and pest risks; (k) impacts on coastal processes. On the lowering of the base level of the river, Padmalal et al (2008) reported a case study in which riverbed in the storage zone was lowered at a rate of 7–15 cm y^{-1} over the past two decades. The

lowering of base level, in turn, causes accelerated river bank erosion which imposes severe damages to the physical and biological environments of the river systems.

A majority of bridge damage accidents are caused by the unreasonable excavation of river sand by altering the hydrodynamics around bridge piers which in combination with reduced axial pile frictional capacity and exposes bridge foundations. Consequently, foundations are scoured, which reduces bearing capacity. The Chinese Code for Design of Bridges Foundation (Peng and Pang 2014) stipulates that the loads on top of friction piles should be mainly borne by pile side resistance. The dredging around bridge foundations loosens the soil, reducing the frictional resistance of the piles, leading to reduced bearing capacity of the pile foundation, thereby threatening the safety of structures and even leading to bridge collapse.

The dredged sand is used mostly for construction and as fill for land reclamation projects. Reclamation has remained a veritable source of creating new land for development in the region, where usable land is a premium. This is due to a combination of factors including: relatively low elevation of the region with respect to surface water level and widespread occurrence of compressible sediments. Extensive areas of swamp land are therefore periodically reclaimed by Hydraulic sand-fill, dredged from surrounding rivers and creeks.

Due to lack of understanding of the ground response to the excavation and removal of surrounding sand materials, such river bed and neighboring river banks progress into degradation, beginning with insipient motions of grains (Porto and Gessler, 1999) and in the process threatening the safety and stability of major coastal infrastructures in the area.

The process of incipient motion and suspension in natural rivers is closely related to the problem of critical shear stress of sediment mixtures Shields (1936), van Rijn (2022). Shields (1936) proposed his widely accepted criterion for incipient motion of uniformly sized bed material:

$$\frac{\tau_c}{(\gamma_s - \gamma_w)D_s} = f\left(\frac{u_* D_s}{\nu}\right) \quad \text{.....1}$$

Where τ_c = critical shear stress;
G_s = specific weight of sediment;
G_w = specific weight of the fluid;
D_s = diameter of the grains;
u^*= shear velocity; and υ = kinematic viscosity of fluid.

The critical depth-averaged velocities at initiation of motion and suspension for sediment with d50 between 0.1 and 2 mm was proposed by L.C. van Rijn (2022) and presented graphically in Fig. 1.

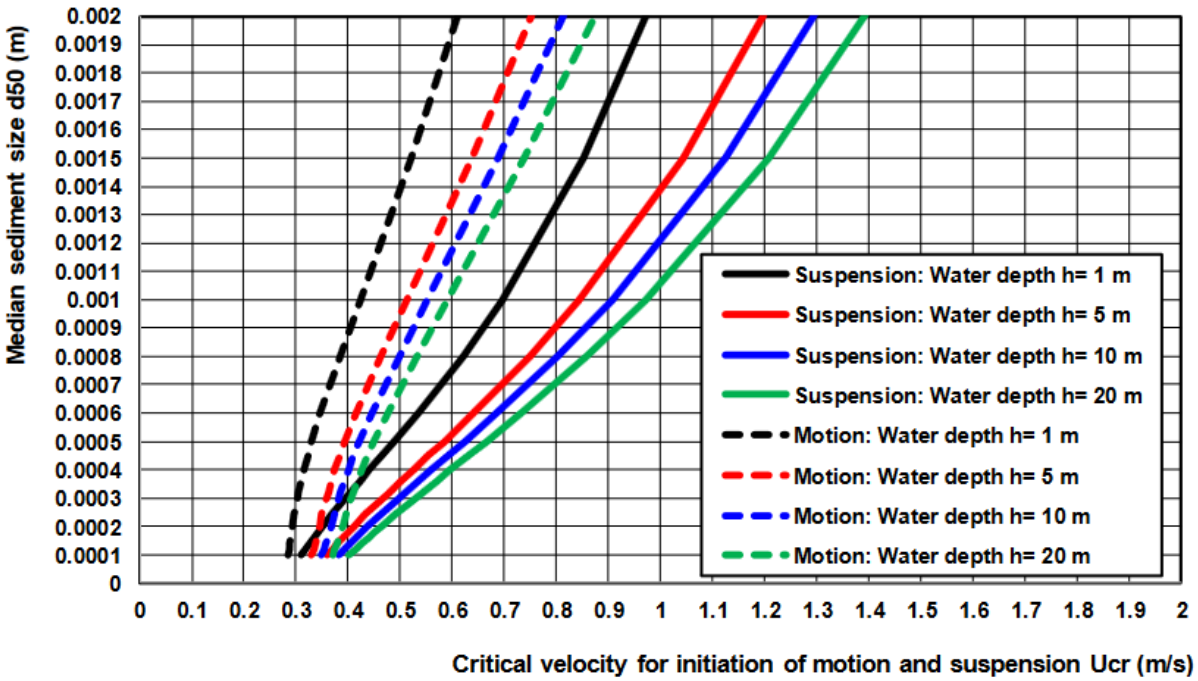


Figure 1: Depth-averaged velocity at initiation of motion and suspension (after van Rijn, 2022)

The applicability of the equations by Shields (1936) and van Rijn (2022) are limited because the criterion was established for uniformly sized bed material, a condition hardly met by all riverbeds in an attempt to generalize the criterion for sediment mixtures a number of authors have suggested the use of a single "representative" diameter for the mixture.

This equilibrium slope of river beds differs from the stable slope of river banks which have been elaborately discussed by several researchers, including, Thorne (1982), Abam (1993), Abam and Omuso (2000). Consequently, two types of equilibrium slopes are implicated by sand borrow in river channels. This paper explores the mechanisms of river bed and bank instability triggered by hydraulic sand mining within river channels and focuses on the Akpajo bridge foundations and abutments to illustrate the dangers posed to its stability and safety, and to ensure that sand extraction is carried out in a sustainable way to maintain river equilibrium by determining minimum safe distances for dredging purposes.

REGIONAL GEOLOGY AND SITE DESCRIPTION

The geological formations in the area consist of the Quaternary sedimentary deposits, and the Tertiary Coastal Plain Sands, generally referred to as Benin Formation. The Quaternary sediments give rise to alluvial plains. The alluvial plains include the estuarine sediments, which are under the influence of tidal brackish waters along the coast and in the estuaries of rivers and creeks.

The general geology of the area therefore reflects the influence of movements of rivers, in the Niger delta and their search for lines of flow to the sea with consequent deposition of transported sediments. The surface deposits in this area comprises silty and sandy-clays. These surface layers vary in thickness from 4m to about 9m and very rarely 12m before transiting to sandy formation. The sandy layers underlying the silty-sandy clay are predominantly medium to coarse in grain sizes and found to exist in mostly medium state of compaction. It is this sand that is widely extracted through dredging for construction and reclamation.

METHOD OF INVESTIGATION

Tidal data was obtained from records of ADCP measurement in nearby creeks. Information on tidal velocity is important not only for predicting the initiation of particle entrainment, but also for the management of transported/buoyant pollutants, which in this case would largely be silt dislodged by the dredging process. Tidal velocities determine the extent of transport of silt particles re-suspended by a dredging operation and assist in the choice of optimum locations for silt curtains to prevent wide spread silt contamination.

Four borings were made in study sites using a workshop fabricated light shell and auger percussion rig mounted on a portable barge. During the boring operations, disturbed samples were regularly collected at depths of 0.75m intervals and also when change of soil type is noticed. All samples recovered from the boreholes were examined, identified and roughly classified in the field and used in the production of lithostratigraphy of sediments beneath the seabed. Particle size distribution analysis was carried out in accordance with the British standards (BS 1377 of 1990) in order to classify the sandy units.

RESULTS

The river system is subject to diurnal tidal inundation with Mean Tidal level averaging 1.52m. Tidal velocities vary across the tidal cycle, with peak velocities up to 1.4m/s occurring at mid ebb tide (Fig.2), with depth averaged velocities that are able to entrain and transport sediments generated as a result of dredging within the river system.

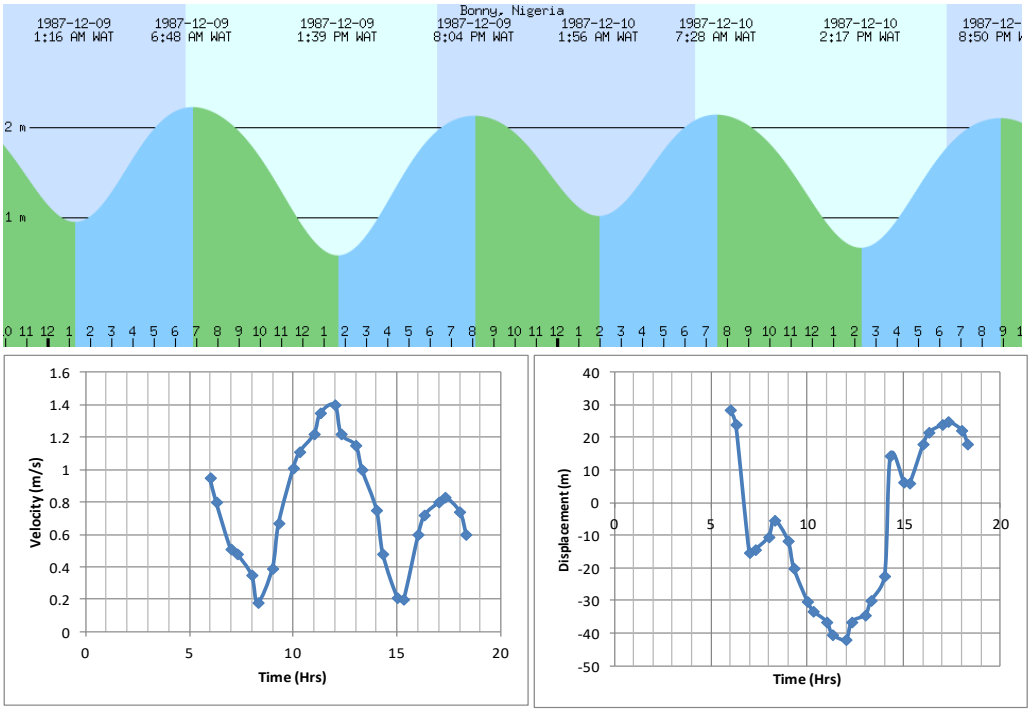


Fig. (2): Tidal regime in study area

The excavation of sand from the river bed created large borrows of 40m diameter and 18m in depth in scattered locations. These pits intercept and trapped bed load, creating a deficit in the transported sediment and disrupting the sediment transport equilibrium of the river/creek. In a bid to re-establish this equilibrium, the river increases its appetite for erosion, beginning from the most vulnerable areas. Firstly, sub-aqueous slope failures will occur in the near vertical slopes of the pits, altering the bathymetry and creating a steeper basal configuration with comparatively

faster flow velocities, with correspondingly higher erosive power and increased capacity for transportation of entrained sediments.

The identification and prediction of the spatial distribution of bank processes, the tendency for lateral channel mobility, and its controlling factors collectively form an important issue. As a first approximation, the lateral mobility distribution at a river network scale can be related to interaction between Stream Energy and boundary resistance. It is also well recognized that bank retreat is the integrated product of three interacting groups of processes (subaerial processes, erosion processes, and mass wasting).

Extraction of aggregates alters the channel geometry and flow pattern, thereby redirecting the main flow trajectory, causing changes in the patterns of erosion and deposition.

CASE STUDIES

An estimated $1.5x10^6$ m^3 of sand has been extracted for various construction activities through dredging of the riverbed between 1980 and 2022. In order to fully appreciate the dredging impact on this river, three case studies on the same river at different reaches as shown in Fig (3) are presented.

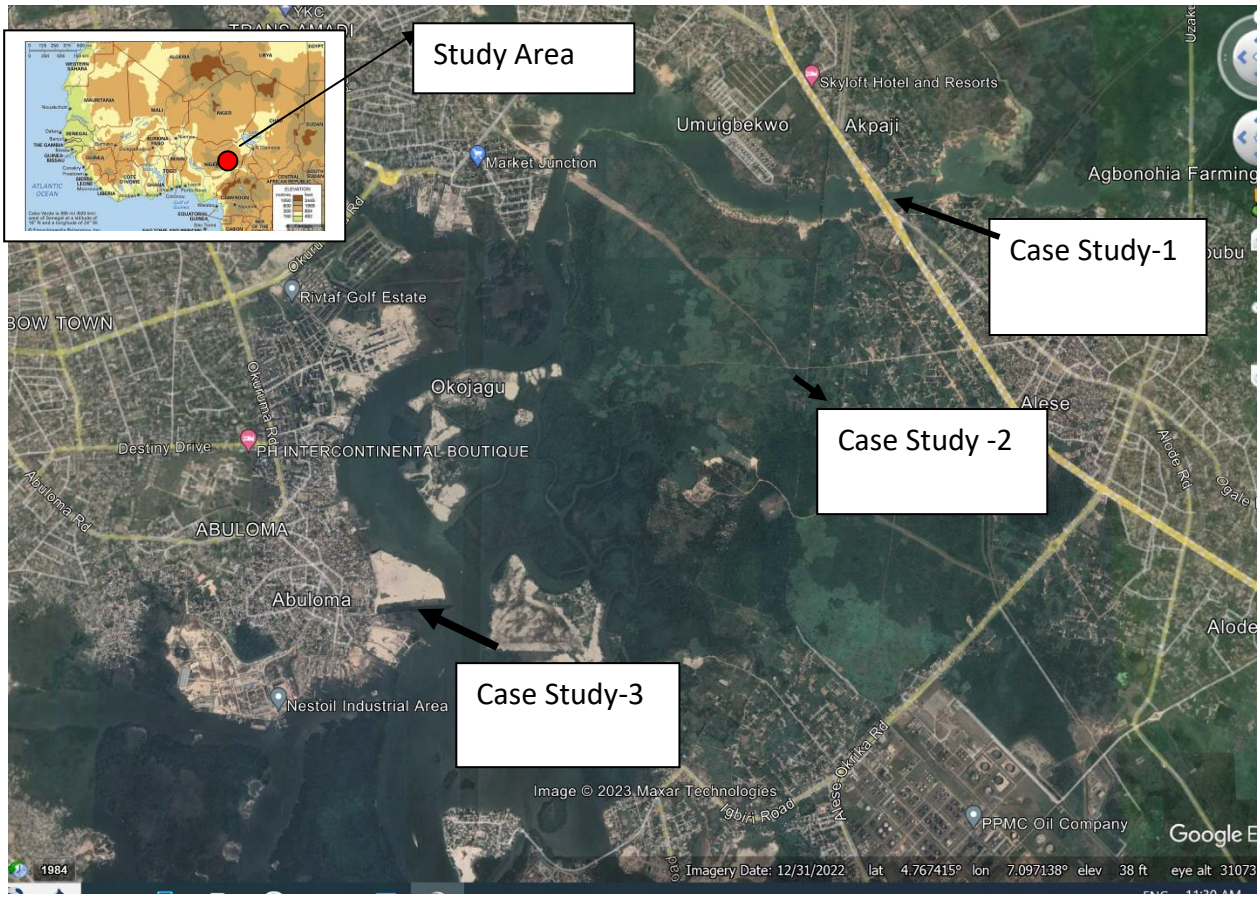


Fig. (4): Relative locations of Case Studies

Case Study 1

Comparative satellite imageries of the Akpojo bridge area in 1985 and 2022 (Fig.4) reveals significant changes in landuse triggered by sand dredging within the creek channel. As a result,

sections of the creek show shorelines that have shifted, resulting in the widening as well as deepening of channel cross-section.

1985 **2022**

Fig. (4): Comparative Satellite images of the Upstream Okpoka Creek at Akpajo Bridge

In much the same fashion, the dredging lowered the basal level, triggering sub-aqueous slope and riverbank instabilities. The evacuation of the additional volume of water in the excavated space within the diurnal tidal cycle implies that flow velocities and by extension the discharge would be increased. Measured tidal velocity based on timing of floats indicated an increase of 37% in the peak ebb tide flow velocity. The combined effect of slope instability caused by basal lowering of the riverbed and the increased tidal discharge through the bridged channel section eroded the abutment and is currently threatening the stability of the bridge itself. Fig. (5) shows the current state of the bridge abutment, with eroded banks and scoured piles which effectively reduces pile capacity.

Fig. (5): Akpajo Bridge abutment deterioration Upstream Reach Okpoka River

Repeated attempts to protect the bridge with crushed stones gabion construction have failed, because the protective structure could not withstand the turbulence associated with the increased flow.

Case Study 2

This case study explores the on-going Worji-Alode Bridge Crossing, some 1km downstream of the Akpajo bridge. This section has steeper and actively eroding banks (Fig.6) as well as deeper basal levels occasioned by dredging of sand in the river channel. Although the soil is generally firm to stiff, they lose strength rapidly when in contact with water.

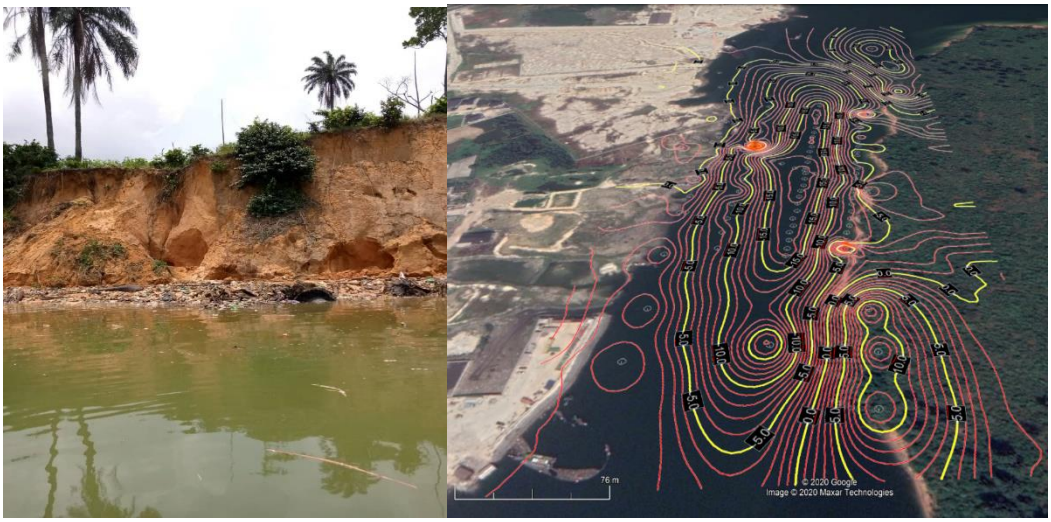


Fig. (6): Riverbank conditions and Bathymetry at midstream Okpoka River at Alode-Worji crossing

The geologic cross-section (Fig.7) shows the preponderance of sand at shallow depths overlain by a firm to stiff sandy clay top soil varying in thickness from 3m to 9m on the Alode end and mostly soft organic clay with thicknesses between 4 to 6m at the Worji end (Table 1). The top of the sand layer coincides with the low-tide level. Fluvial erosion of the top section of the sandy layer results in steepening the riverbank and increasing its vulnerability to failure. Slope stability analysis of the riverbanks indicate factors of safety between 1.1 and 1.3. This state of marginal stability suggests that the emergence of any additional causative factor is likely to cause bank failures. This further implies that additional bank stabilization measures are necessary to protect the abutments as well as coastal infrastructure in the area.

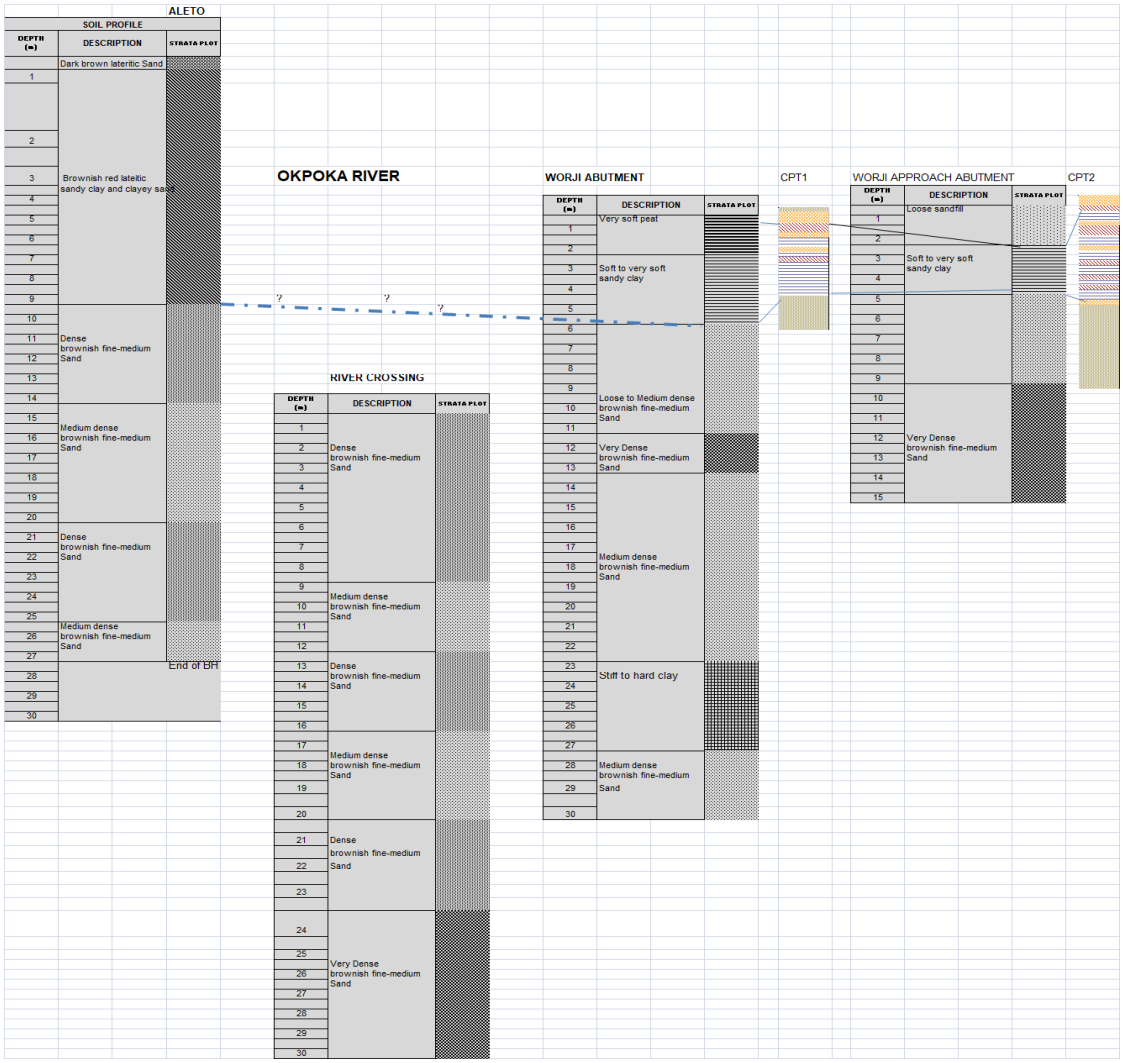


Fig. (7): Geologic cross-section of the midstream Okpoka River

Table (1): Geotechnical properties of the riverbank soils

BH No.	Depth (m)	Natural Moisture Content (%)	Bulk Unit Weight γ (kN/m³)	Undrained Cohesion Cu (kN/m²)	Friction Angle φ (Deg.)	LL	PL	PI	Description of Sample
1 (Alode end)	1.5	13.5	20.7	75	11	30.2	9.2	21	Stiff dark brown sandy clay
	3	12.7	20.3	98	13	27	8.9	18.1	Stiff reddish dark brown silty clay
	6	14.8	20.4	90	16				Stiff reddish brown sandy clay
3 (Worji End)	3	26	16.2	16	2	22.7	15.7	7	Very soft to soft dark grey silty clay
4 (Worji End)	3	49	15.3	25	2	23.3	16.8	6.5	Soft to soft dark grey silty clay

Case Study 3

This case study explores the incidence of accelerated erosion triggered by dredging neighbouring sections and deepening of river channel up to 14m (Fig.8). This activity compromised the functioning of a drainage channel, resulting in discharge redistribution and consequently accelerated erosion (Fig.9). By measuring channel dimensions and flow velocity, discharges from the interconnected drainage channels were computed and compared to values prior to dredging. The results indicated 30% increase in discharge through the tertiary channel, suggestive of lateral channel expansion, which is equated to accelerated bank erosion, of approximately 3m.

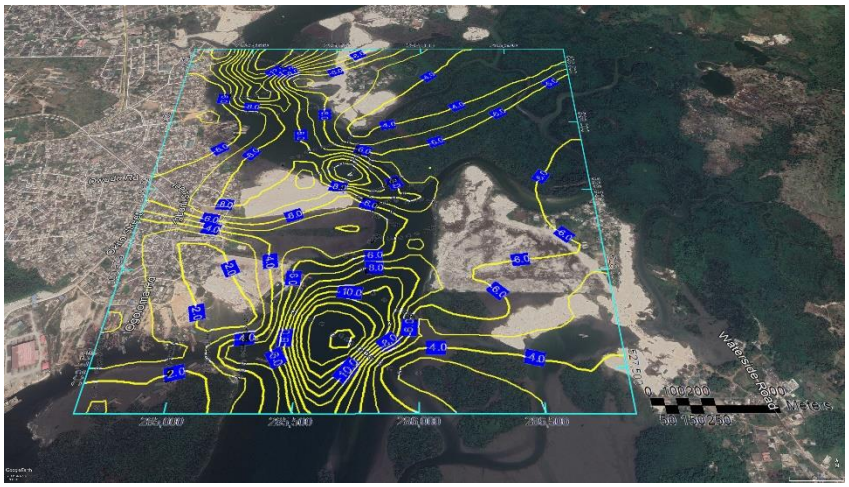


Fig. 8: Bathymetric contours superimposed over Satellite imagery of section of study area

Fig. (9): Failed sections of River Bank due to accelerated erosion

DISCUSSION

Assessment of Threat to Bridge and Other Coastal Structures

One major consequence of dredging the Okpoka River is the deepening of the water channel which has implications on the stability of coastal infrastructure and river banks, besides the dislodgement of aquatic ecosystem and effects on the physical hydrology. In some cases, these potential effects are evaluated during Environmental Impact Assessment.

To further illustrate the effect of channel deepening on bank stability, the channel cross-section at the narrowest reach was 50m wide and 3m deep in 1980. By 2022, this section has widened to 95m and 8m deep. This translates to a discharge of $2.43x10^5m^3$/hr in a tidal cycle in 1980 against $3.28x10^6m^3$/hr in a tidal cycle in 2022. The discharge of such large volumes beyond the design discharge is bound to scour the bridge piers and erode the abutments, the evidence of which is already manifested in Fig. (5). Furthermore, dredging of the riverbeds deepens the basal level of the riverbanks, making them less stable and more erodible. Due to the narrow width of the channel close to the bride, the effect of lowering the basal level on bank stability is felt much faster. The deeper the sand Burroughs, the wider their potential lateral impact on the channels.

The minimum safe distance from river bank or bridge structure to dredge point has already been determined by Abam *et al;* (2023) considering angle of repose of dredged sand materials in the area. In general, environmental safety of the river bank requires that as a minimum horizontal distance, X is greater than d/Tan (Angle of repose); i.e, the ratio (d/X) should always be less than 0.32 and must not exceed 0.40.

The angle of internal friction in shear test, which approximate the angles of repose, ranged from 26° to 32°. Under submerged conditions, these angles would range from 28° to 33°. Applying a factor of safety FS = 1.5; these angles of repose would then range from 18° to 22°. At FS = 2.5 which takes account of the sensitivity of the coastal infrastructure, the corresponding angles of repose would be 11° to 13°, which would translate to a minimum safe distance of 94m for a dredging operation requiring a dredging arm with a capacity of 18m of dredged depth.

The instability created by the presence of a sub-aqueous borrow pit would extend over an area, the longitudinal extent of which can be estimated by considering the schematics in Fig. (10).

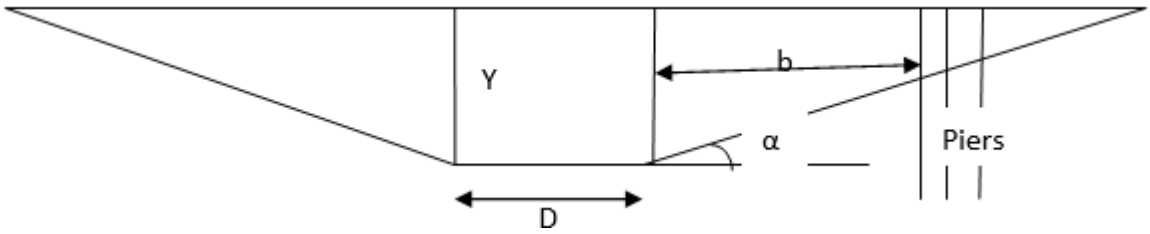


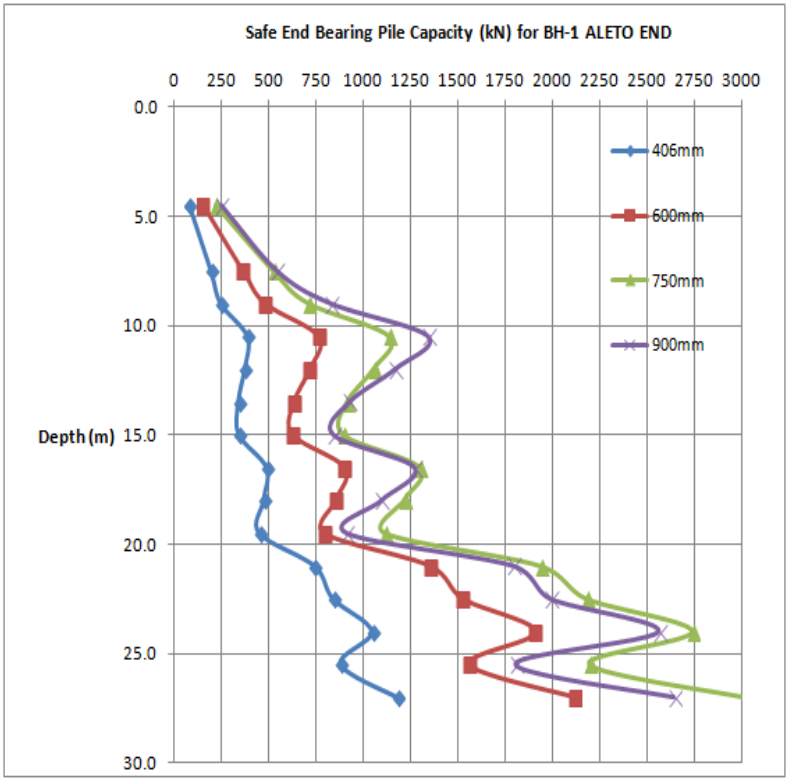
Fig. (10): Schematics for assessing area of influence of sub-aqueous borrow pit

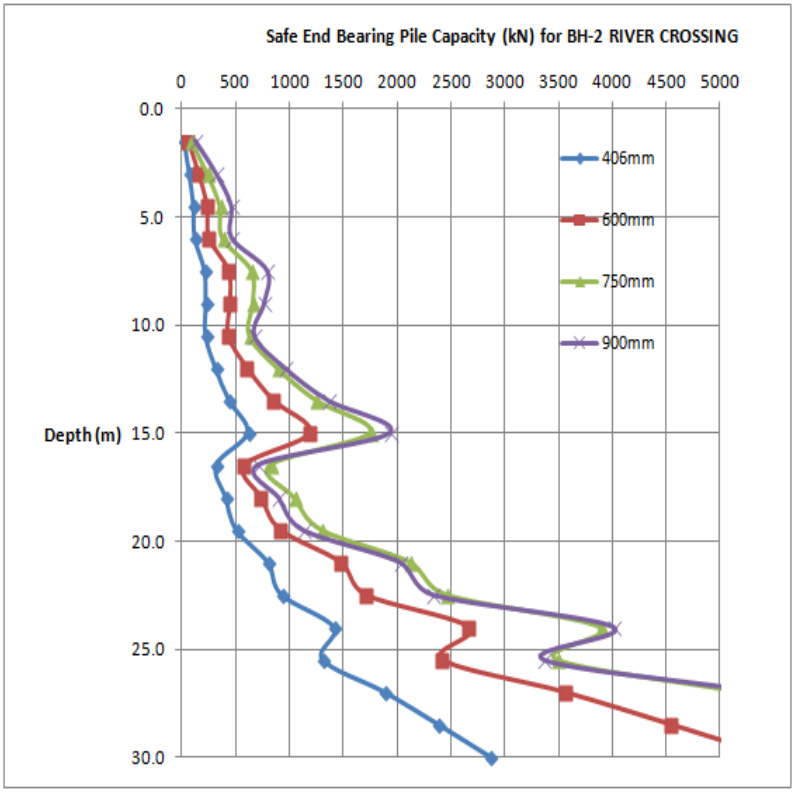
α = angle of repose
D = diameter of borrow pit

The implication of this is that, if the measured width of a river channel is less than the predicted safe distance, then river bank instability induced by dredging is imminent.

The potential for scour for the bridge foundation and abutment was also assessed based on the hydrology of the study area, with tidal velocities peaking at 1.2m/s. The turbidity of the water indicated the movement of substantial suspended load in the flow. Since there is reasonable narrowing of the flow area at bridge crossing location, the river flow velocities are expected to increase significantly. Under these flow conditions, it is highly probable for the development of scour around the bridge piers and abutments. Furthermore, if a bridge pier is within the area of influence of a borrow pit, then it is probable that additional scour arising from bed instability

caused by the pit can be introduced. Such scour is to be checked against the depth of pile embedment in order to assess its significance with respect to the continuing stability of the pile or pier as the case may be. Fig. (11) presents the axial pile capacities for various pile diameter on the proposed Worji-Alode crossing. Scour resulting in the removal of 8m of bed material is expected to reduce axial pile capacity by 34% or more.





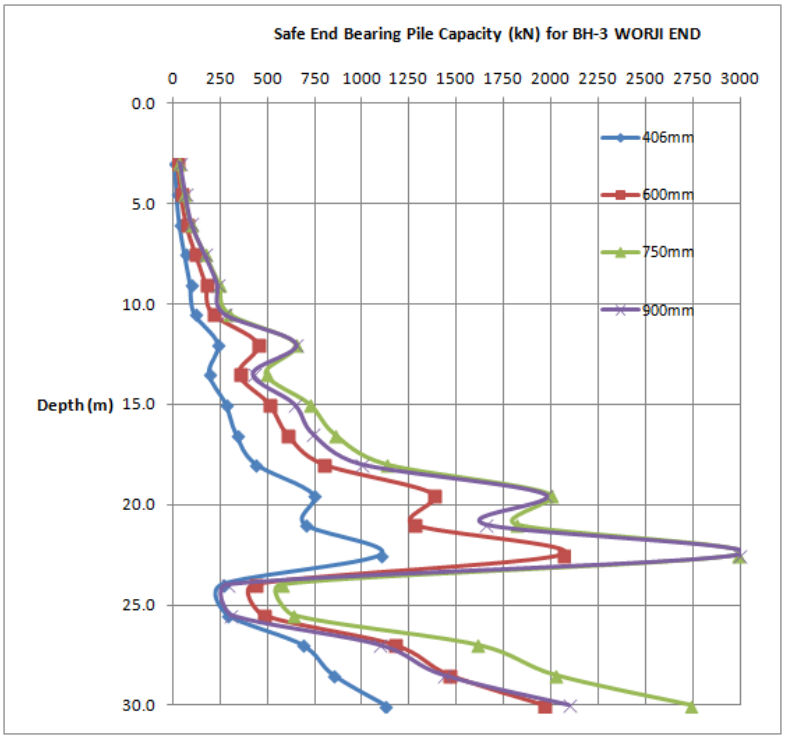


Fig. (11): Axial pile capacity of driven piles across the Okpoka River.

CONCLUSION

Sand mining from river beds has considerably altered the river form and is threatening the stability of coastal infrastructure. Bridge foundations as well as abutments can be vulnerable to scour and erosion, if the choice of dredging locations on river channels are not properly guided. There is need to develop regulation for sand mining activities in inland rivers. Based on this study it is shown that a minimum distance of 94m (for sand river beds) from a bridge should be observed to guaranty the safety of bridge foundation. Furthermore, it is concluded that the ability of sand borrowing in river channels to generate bank instability is dependent on the composition and stratigraphy beneath the river bed.

RECOMMENDATION

There is a need for the Ministries of Environment to be equipped with the necessary planning and management tools to deal with the problems that arises from river sand mining and this study is an effort in this direction.

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Bridging Innovation Gap and Technology Transfer in Managing Public Organizations

Ugochukwu Okwudili Matthew

Abstract:
The benefits of the digital workplace technology applications, and their potential shortcoming have all been brought into sharp view by an intensification of digital employees pushed by Covid-19 outbreak. In this paper, the authors discussed how digital automation is changing workplace cultures, along with how employee users in an academic setting are utilizing computers and other digital technologies. The digital experiences of today's society have provided justification of how people use modern computers and how they affect our daily lives as a whole. In order to understand how individual experiences with technology use occur, it is necessary to look into human-computer interactions that deal with knowledge, experiences, and technology use. High levels of negative experiences were found in our study of 137 female and 107 male workplace computer users. Primary and secondary sources were used to collect the survey's data. Using frequency percentage tables, descriptive statistics, and SPSS to test the hypothesis, the acquired data were examined using Chi-Square distribution. The research's conclusions indicated a high level of feminist gender frustrations because some users suffer loss of control and bad emotions when faced with digital frustrations.

Keywords: Computer Experiences, Human Computer Interaction, User Frustration, Knowledge Divide, ICT, Digital Interactivity, Digital Divide

INTRODUCTION

Digital computing experiences are a global phenomenon arising from people's desire to employ contemporary technologies to fulfill their day-to-day computing requirements in the working places (Iqbal, Doctor, More, Mahmud, & Yousuf, 2020). The demand for information communication technologies (ICTs) based development is a universal issue that has long been and will continue to be of enormous importance to all humankind, steering discussions on matters of public importance. The ICTs are the computers, software, networks, satellite linkages, and related systems that enable people to access, analyze, produce, share, and use data, information, and knowledge in ways that were previously unthinkable. The widespread adoption of ICTs and their quick development have shifted human society from the information era to the knowledge driven economy in nearly all fields. Digital technologies are fundamentally altering the topologies of organizational work cultures through increased automation, which has encouraged new work ethics and a well-organized value chain that have resulted in productivity(Barakabitze et al., 2019). Previous investigations into how technology is affecting modern workplaces have mostly focused on the physical limitations of digital automations and have heavily considered both the workplace environment as being immovable and technology as being exogenously dynamic (Jain & Srinivasan, 2018).

While recent developments involving digital automation have had a significant impact on the technology sector, other economic sectors have also benefited fairly from the diffusion of new technology. The ongoing digital automation of the working environment and the integration of digital technology into many economic sectors signify economic transactions through digital

networks of cutting-edge technologies for process modernity(Hassan, 2020). Given the socioeconomic dynamics and how deeply ingrained production technologies are in organizational social structures, the introduction of new technologies will initially face resistance from preexisting institutional configurations, vested interests, and organizational arrangements(Sweet & Meiksins, 2020). The same organizational structures, interests, and institutions, on the other hand, will adapt to the distribution of technology and subsequently advance the development of the novel technologies once the first digital resistance is overcome. In this way, the digital revolution will stand in for the series of irregular spurts of novel changes, tools, and processes used in the larger economy(Frey, 2020).

On the organizational job allocation and individual performances, the early workplace automation will have far-reaching effects(Arntz, Gregory, & Zierahn, 2020). Up to 35% of the workforce may need to upgrade their skills and change their occupational disposition while technological innovation will increase economic growth and occupational productivity, particularly in developing nations(Mello, Ludolf, Quelhas, & Meiriño, 2020). For managers, decision-makers, trainers, and staff, the new work environment will reflect optimism along with worries and thought-provoking projects. Although the mismatch between occupational skills in the educational and industrial sectors is not new, the worry is growing as a result of the rapid advancement of technology. Unquestionably, digital skills are becoming essential for a large number of people who are living and working in the digital world today, and this trend will likely continue into the foreseeable future (Gilman, 2016). As seen from a gender perspective, women's workplace contributions are rapidly declining due to rising digital automation, and they exhibit the highest rates of digital phobia, poverty, and declining pay when compared to their male colleagues (Asi & Williams, 2020). The economic disparities revealed information about the distribution of occupations and offered advocacy tactics for improving economic justice for women in the workplace in the current, highly automated society(Gilman, 2016). There exist events that typically constituted an occupational effects of a bad computing experience, reflecting a global world shortages of competent persons, and perhaps lowering the performances of women's gender representation in information technology (IT) dominated workplaces (Bullough, Guelich, Manolova, & Schjoedt, 2022).

One of the fastest-rising economic trends of the twenty-first century is IT-driven organizations, which have the potential to hire more women(Lapsomboonkamol, Songkram, Thamsuwan, & Songkram, 2022). However, when IT was first implemented in organizations, it was thought to be a gender-neutral automation, similar to that in Western nations, but the IT results in the organizations seemed to be favorable to exclusively men(Cetindamar & Beyhan, 2019). When computers are difficult to use, interfaces appearing poorly designed, and people are unable to conform to computing expectations, this causes worry that the user won't be able to complete the task. The outcome led to user frustration, impacting user mood at work, effecting productivity level and interactions across the entire organizational ecosystem. Digital gadgets can be useful tools, and networked materials accessible through the Internet can benefit a variety of user communities and groups. Unfortunately, when people have frustrating encounters and are unable to complete their intended tasks, this hinders their ability to work effectively with the technology not minding the degree of sophistication. In the digital age, everyone is aware of computer issues and the aggravation that results when a computer application crashes unexpectedly, internet connectivity fails, input and output devices malfunction, and the system is unable to accept or process data into useful information. When the computer behaves in an unanticipated way that irritates users and prevents them from completing their desired tasks, frustration results (Jhaver,

Appling, Gilbert, & Bruckman, 2019). It becomes essential that users had unpleasant computing experiences afterward.

Computer users frequently contend with lengthy delays, incompatible application files, malfunctioning input/output devices, difficult-to-understand menus, and system crashes, all of which are recurrent motifs in their negative computing experiences(Lazar, Jones, Hackley, & Shneiderman, 2006). Users' negative computing experiences are clearly a serious problem that is strongly related to the digital divide. Due consideration must be given to documentation, tutorials, training, online user assistance, and helpdesk support for a user to use computer technologies efficiently(Cavus, 2013). In contrast to technical access, social access to technology includes things like user support, technical expertise, and a network of individuals who can assist(Kendall, Chaudhuri, & Bhalla, 2020). Even with the most up-to-date hardware, software, and network connections, users may still find poorly designed technology challenging to use. It is not sufficient to simply provide technology to those who are economically disadvantaged; effective closing of the digital divide calls for superior designs and a willingness to adapt, adopt, and collaborate to achieve outcome in the employment setting(Ma, Chan, & Teh, 2020). Only when people have support to use the technology properly and well-designed systems that are not frustrating can successes emerge. This study offered details on how users interacted with computers and computing tasks in an employment setting.

REVIEW OF RELATED LITERATURE

Service automation is now required due to the shift in the workplace in the twenty-first century from traditional manufacturing to IT service oriented industries (Li, Hui, Lang, Zheng, & Qin, 2020). All organizations have adopted IT since it has been recognized as one of the key vocational competencies that analysts believe will be absolutely necessary in practically every position in the future (Holford, 2019). The ongoing COVID-19 global pandemic had recently caused a set of computational paradigm shifts that the world had recently witnessed. These changes, which were fueled by the introduction of 5G network technology in the context of global automation with all of its opportunities and difficulties, were characterized by the Internet of Things (IoT), artificial intelligence (AI), robotics extreme automation. These changes helped countries perform better and the healthcare service sector to fulfill its key mandates. The COVID-19 epidemic, which is still continuing strong, has put a strain on the healthcare industry and forced medical experts to deal with the difficult situation of treating those who have only the tiniest social and physical connections with infected people. A number of healthcare technologies were created to help hospitals operate more efficiently because of the concern that workers in the healthcare industry would stand to gain from technological advancements in the ongoing COVID-19.

In the era of extreme digital automation in the twenty-first century, the idea of the Internet of Medical Things has arisen as the foundational element of the IoT promise for breakthrough in healthcare computing(Onyebuchi et al., 2022). The growth of enterprise 5G network infrastructures have made it necessary for billions of low-bit-rate, low-energy linked health monitoring devices, remote sensors, and clinical wearables to rely on the enterprise IoT framework and 5G network backbone infrastructure connectivity. Doctors, physicians, and healthcare providers will primarily rely on linked devices to gather, analyze, and digitally communicate patient data to those who will influence decision-making. In this case, real-time synchronized data retrieval and processing will enable healthcare providers to efficiently review all obtained electronic data and draw conclusions. The widespread adoption of IT should be gender-neutral because of the relatively innovative nature of the IT categorization, which means

that all associated technologies should be user-friendly to both women and men within the job distribution. Given that ICTs play a crucial strategic role in achieving gender equality and empowering women to take the lead in social justice, environmental ecosystem sustainability, and economic development, the relationship between gender and ICTs is extremely important in achieving sustainable occupational satisfaction(Kerras, Sánchez-Navarro, López-Becerra, & de-Miguel Gómez, 2020). As a result of recent advancements in information technology, processing power, data rates, connectivity, display size, and network transmission quality have all significantly increased. All of these developments raise the chance of unique experiences and the demand for reliable solutions(Hashem et al., 2015). Users generate opinions about particular technical concepts based on whether they believe those concepts to be practical, adaptable, simple to use, or horribly awkward(Tsai, Cheng, Tsai, Hung, & Chen, 2019) . When such conclusions about a particular technology's utility are made, people build positive use-performance strategies, adapt, form corporations, and share information on insightful findings.

Additionally, when new technology is used in a setting, the likelihood that it will have the most positive effect on job improvement is when it is appropriately built for the tasks that employees of the business will be performing(Afsar, Badir, & Khan, 2015). Each and every one will adopt the technologies and tools that will enable them to finish their assigned duty effectively and with the most profit. Technology or digital diffusion happens over a set period of time, with inventions going through a long and gradual growing process, followed by a sudden and dramatic adoption that eventually establishes and is then optimized. The amount of time a technology has been available to users has a direct correlation with how quickly an individual adopts it. The acceptance of any particular technology advancements by organizations is comparable, particularly in academic settings(Crupi, Del Sarto, Di Minin, Phaal, & Piccaluga, 2020). Information and communication technologies (ICTs) experiences will be the main focus of the ongoing changes in twenty-first century occupational proficiencies and extreme digital adjustments. The twenty first century learning possibilities, which stress digital-age literacy, creative thinking, efficient communication, and high organizational productivity, will be strengthened by the acquisition of digital skills through ICTs activation. Digital abilities for the twenty-first century, however, go beyond computer literacy and also include the capacity for critical thought, problem solving, communication, and teamwork.

Users have to react to unexpected, ambiguous, and potentially task-interfering situations when handling the general computing element. Frustration happens when users are unable to complete their work owing to inevitable digital complications, according to social psychology study literature(Dobrosovestnova & Hannibal, 2020). Users may be unable to complete their tasks and may experience emotional reactions such as frustration as a result of their inability to do so. Poor interface design, problematic computer hardware, unreliable software, or even users' ignorance of computer technology could be the root of the issue and result in digital annoyance (Fairbanks & Caplan, 2004). This is particularly relevant given that automation in modern workplaces has altered the makeup of computer users, introducing a larger proportion of non-technical workers with limited or no proficiency in disruptive technologies(Tribble, 2020). Employees are increasingly reluctant to use computers or avoiding digital automation completely due to technology frustration(Kadir & Broberg, 2020). According to the research conducted by (Lazar, Jones, & Shneiderman, 2006), a significant portion of people (42%) avoid using the internet because they perceive it to be excessively annoying and negatively affecting their digital orientation(Ceaparu, Lazar, Bessiere, Robinson, & Shneiderman, 2005). It may not be surprising to learn that employees waste between one-third and half of their computer time dealing with

uncomfortable situations, according to numerous studies on user annoyance with computing(O'Driscoll, Brough, Timms, & Sawang, 2010). On the other side, complicated computer technology can result in decreased levels of job satisfaction, as well as possible increases in blood pressure and muscular tension. In one survey, approximately 80% of employee computer users admitted to swearing out at a bothersome ICTs computing device(Onwubiko, 2022). The organizational employees had frequently been enraged, driving them to take extreme measures like shattering the computer screen or tossing the machine out the window(Adler-Nissen & Eggeling, 2022).

Digital Divide

Although ICTs have been integrated into the employment settings and educational systems of the majority of African nations, their adoption and growth have been sluggish because of a lack of effective ICT policies, long-term ICT infrastructure (such as electricity, Internet, software, and hardware devices), teacher capacity, and financial resources(Barakabitze et al., 2019). As a result, the use of ICTs in education and the general transformation of African Educational Systems (AES) in science, technology, engineering, and mathematics (STEM) using ICTs, particularly in a minority of African schools, have the potential to widen the digital gap due to a number of socioeconomic variables. This study offers a thorough analysis of cutting-edge approaches and ICT-based frameworks with an emphasis on reforming Africa organizational workplace and educational environment utilizing ICTs(Gumel, Abdullahi, & O, 2019). In fact, new ICT project developments and announcements of ICT for education (ICT4E) projects happen somewhere on the continent virtually every day. But for many years, we have observed that investment has been directed on making new technologies work in educational settings with limited resources, a focus that tends to take an ICT-centric approach. The promotion of ICT4E integration in AES is crucial for reshaping African society's development through STEM courses in this era of knowledge, regardless of how well understood ICTs are in education now. The future of AES clearly calls for innovative approaches and solutions that prioritize teachers' use of ICT as a crucial tool to support instruction and outfit learning institutions with the required IT infrastructures.

The adoption of ICT policies by African countries continues to support growth in a variety of socioeconomic sectors (including education) and to guide growth and competition. The information and digital economy that emerged in the twenty-first century wasn't just a transition from an industrial-based economy to one that reflected technological and automation models; rather, it was accompanied by revolutionary changes in many important spheres of human endeavor, especially the labor-intensive culture that had aided in the promotion of social diversity and structural inclusiveness(Kerras et al., 2020). In this regard, the ongoing technological advancements and regular ICT advancements were key drivers in the development of the information society. A disparity in access to ICTs or IT in general is referred to as the "digital divide." (Scheerder, van Deursen, & van Dijk, 2017). The digital divide was once thought to be a matter of having access to or not having access to current technologies, but with the global prevalence of mobile phone technology at over 95%, it is now more of a matter of those who have more or less internet bandwidth and more or less digital competences(Reddick, Enriquez, Harris, & Sharma, 2020). However, study revealed that the digital divide is more complex than just a problem with access to technology and cannot be solved by simply giving the required computing hardware. Information accessibility, information use, and information receptiveness are the three main elements that reduce the incidence of the digital divide(Jang & Gim, 2022). The purpose of information technology professionals is to help close the gaps in the digital divide by offering resources and information services to aid people in learning how to use the technologies at their

disposal in the twenty first century for comprehensive digital inclusive smart society(Blažič & Blažič, 2020).

Knowledge Divide

The knowledge economy and digital ecosystem have emerged as a result of the pervasiveness of twenty-first-century digital work environments(Lyons, 2019). The digital adaptations of the modern global economy of value, which is characterized by a paradigm shift in ICT, have the potential to alter the global economy (Espino-Díaz, Fernandez-Caminero, Hernandez-Lloret, Gonzalez-Gonzalez, & Alvarez-Castillo, 2020),(Kostoska & Kocarev, 2019). Due to the emergence of disruptive technologies, digital knowledge is becoming increasingly important for the employment environment in today's society. The adoption of mass media information democracy has encouraged the phenomena of knowledge gaps within the educational classes(Lind & Boomgaarden, 2019). The discrepancy in living standards between those who can find, produce, manage, process, and share information or knowledge and others who are hampered in this endeavor is known as the knowledge divide(Zhou et al., 2022),(Liu, Yang, Li, & Zhong, 2022). According to the 2005 UNESCO World Report, the growth of the information society in the twenty-first century has caused knowledge to become an expensive resource, gradually affecting who has access to power and financial gain(Cowell, 2006),(Chan & Costa, 2005). Rapid information dissemination on a massively global scale as a result of breakthrough information media technologies had the potential to widen knowledge gaps between people, organizations, and countries(Anton, Silberglitt, & Schneider, 2001). The general concept of knowledge gap, however, was actually a representation of the differences in knowledge composition between various personalities, including racial, gender, and socioeconomic groups. The digital gap, on the other hand, separates people and countries according to whether they have access to contemporary internet, disruptive technology, and scientific knowledge(Warschauer, 2004),(Bianco, 2022).

Several researches on general computer technology automation and frustration severity like those conducted by (Yang & Dorneich, 2018), measured how often frustration occurred, what caused frustration and how bad the experience was in educational learning. The study identified the factors that end users find frustrating, including difficult-to-understand error messages, failed network connections, and hidden elements on the human computer interface (HCI). According to studies, digital frustrations are a significant issue that stem from the perspectives of the knowledge and digital divides and need to be addressed thoroughly. Self-reported high levels of annoyance and wasted time were among the top worries in the severity of human computer frustration, it became clear from various developments(Preece, Sharp, & Rogers, 2015). Understanding the causes and recurrences of user annoyance is a crucial first step in learning more about how to lessen the degree of workplace annoyance. Additional studies looked on the automatic detection of users' stressful employment experiences and how computer systems and interface designs could react to those events.

STATEMENT OF PROBLEM

All across the world, academic institutions, businesses, enterprises, and individuals are investing a substantial sum of money in computing technology, educational software, computers, and broadband Internet connections as requirement for ICT implementation(Duderstadt, Atkins, Van Houweling, & Van Houweling, 2002),(Istiningsih, 2022). In order to empower students to fully participate in today's digital society, teachers must provide them with the knowledge and technological know-how necessary to lead in a technologically advanced society and motivate

them to use online learning resources. However, the investigation of digital technologies was to consolidate the pre-existing nomenclatures of education, such as student evaluation, school administration, and managerial activities, which justified the use of computer technology in the classrooms(Mcelhinney, 2018). The most upsetting outcome for the employee users was the significant amount of time lost as a result of their difficult experiences integrating digital technology. Owing to the reasonable amount of time lost in front of the computer due to frustrating encounters, productivity may have decreased. Additionally, the impact may have harmed interpersonal interactions, such as those between students and teachers, as the outcome affects user mood.

In order to better understand how instrumental (the incident scenario) and dispositional (the individual's traits) elements affect the level of dissatisfaction, these social repercussions of frustration for women gender users were investigated. In our first analysis of data from female computer users, we found that 33% of users in the survey expressed anger toward the computer as a result of a difficult experience. Despite the fact that just 11% of users admitted to being annoyed at themselves, 25% of users said they felt overwhelmed or defeated, suggesting that some users do indeed feel a loss of control while dealing with computer issues. However, 17% of the users were determined to solve the issue, which may be related to the high degree of experience the subjects claimed. Another investigation of data from computer users of both sexes, men and women, looked at comparable statistics. The most often mentioned specific sources of annoyance were power outages (reported by 38% of respondents), lack of internet access (35%), computer hardware issues (indicated by 5%), incompetence/lack of technical expertise (cited by 2% of respondents), and software malfunction (20%).

RESEARCH PURPOSE

The goals of this study were to:

1. Present information about the social effects of computer users' bad computing experiences.
2. Examine the effects of unpleasant computing encounters on female employee users to see whether any emotional reactions occur. In order to achieve this, we first developed a standard framework for analysis, reanalyzed the data from male computer users, and then carried out the identical analysis on female staff users before drawing findings.
3. To determine the uses of computers in the academic setting.
4. Techniques for raising employee women's and men's computer proficiency levels in order to balance out positive computing outcomes.

RESEARCH METHODOLOGY

Primary and secondary sources were used to collect data for this investigation. The dissemination of the questionnaires to the randomly chosen participants was necessary for the primary sources. The secondary sources of data, on the other hand, combined digital archives with academic works that examined the topic of discontent with digital technology. The study was conducted in 2019 as part of academic research work. The study's objectives were used to create a thorough questionnaire that was given to both men and women at the beginning. 120 men and 250 women employees who were chosen at random took part in the survey. Male employees returned 107 out 120 questionnaires distributed and 137 questionnaires from women gender were returned for a response rate of 88% and 56%, correspondingly.

SAMPLE AND POPULATION OF THE STUDY

This study employed a demographic sample made up of tertiary school personnel from South Eastern Nigeria who used computers at work (both male and female). The necessary sample size of 250 female and 120 male staff users of computers and computing activities was chosen using proportionate stratified random selection. When necessary, the researcher employed a questionnaire and in-person interviews to gather data, and descriptive statistics were used to analyze the data in relation to the study topics. Out of the two hundred and fifty (250) and additional one hundred and twenty (120) copies of the questionnaire that were distributed among the female and male employee computer users regarding frustration with computers and computing equipment in the office. One hundred thirty-seven (137) questionnaires from female staff computer users and another one hundred seven (107), representing response rates of 55% and 89%, respectively, were duly completed, returned, and deemed appropriate for the study. These users, who recorded their experiences using their computers at work, were either computer professionals or not. The study tools employed for the male and female participants were the same.

HYPOTHESIS OF THE STUDY

In analyzing the hypothesis, two options were analyzed which include Null Hypothesis ($\mathbf{H_o}$), and the Alternative Hypothesis ($\mathbf{H_1}$). In this study, the following hypothesis has been formulated to guide the research outcome.

Null Hypothesis (H_o).

a. User computing experiences, whether positive or negative, are heavily influenced by the digital and knowledge divide.
b. User emotional and psychological responses are impacted by the state of computing devices.

Alternative Hypothesis (H_I)

a. User computing experiences are not caused by the digital or knowledge divide.
b. The emotional and psychological responses and dispositions of the user are unaffected by the state of computer devices.

DATA ANALYSIS

Demographics of the Sample Population

Table 1: Distribution of Respondents by Gender

Female	146	60
Male	98	40
Total	244	100

Field Survey, 2019

According to Table 1, Fig. 1, 146 respondents (60%) are women, while 98 respondents (or 40%) are men.

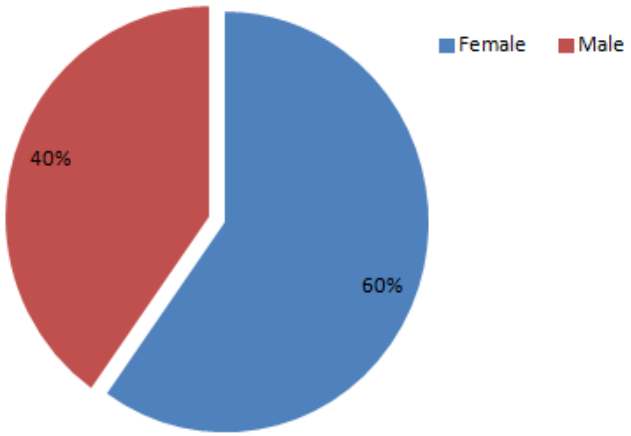

Fig 1: Gender Distribution of the Study

Table 2: Duration of the Respondents' Computer Experience.

Years	Frequency	Percentage%
1-5 Years	50	21
6-10 Years	80	33
11-15 Years	54	22
16-20 Years	42	17
21-Above	18	7
Total	244	100

Field Survey, 2019

According to the data in Ta ble 2 above, 50 (21%) of the respondents had computer experience between one and five years, 80 (33%) had computer experience between six and ten years, 54 (22%) had computer experience between eleven and fifteen years, 42 (17%) had computer experience between sixteen and twenty years, and 18 (7%) had computer experience at age twenty-one or older.

Table 3: Level of Education of the Respondents

Qualification	Frequency	Percentage (%)
OND	10	4
HND/BSC	96	39
PGD	50	20
MSC	78	32
PHD	10	4
Total	244	100

Field Survey, 2019

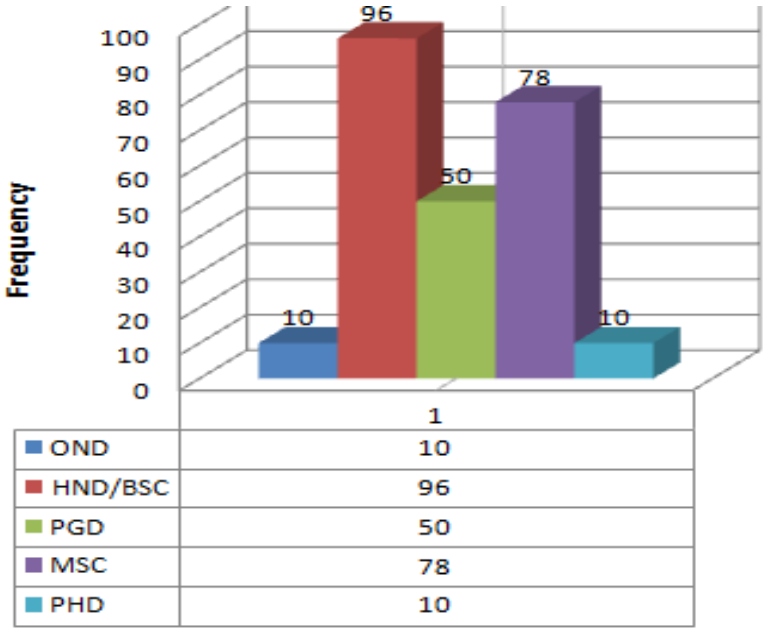

Fig. 2: The Educational Level of the Respondents

According to data in Table 3 and Fig. 2, 10 (4% of the respondents) have an OND that has been completed or is expected to be completed; 96 (39%) have an HND or BSC that has been completed or is expected to be completed; 50 (20%) have a PGD; 78 (32%) have an MSC; and 10 (4%) have a PHD. These people work in information technology, either professionally or not.

Table 4: The Respondents' use of devices for Internet information searches.

Computing Devices	Frequency	Percentage %
Smart Phones	220	31.42857143
PDAs & Portables	50	7.142857143
Tablets	20	2.857142857
Laptops	180	25.71428571
Desktop	230	32.85714286
Total	700	100

Field Survey, 2019

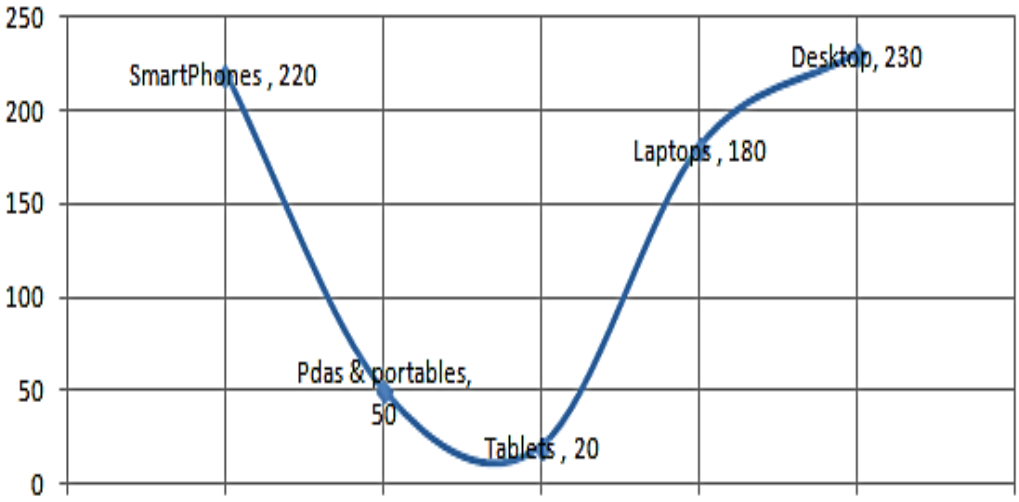

Fig.3: The Device Utilization by the Respondent

According to data in Table 4 and Fig. 3 above, 220 respondents (31.4%), 50 respondents (7.1%), 20 respondents (2.9%), 180 respondents (25.7%), and 230 respondents (31.9%) utilized smartphones, tablets, laptops, and desktops, respectively.

Table 5: The distribution of respondents' computing device requirements

Purpose of Use	Frequency	Percentage
Research Uses	160	29
Social/Communication	140	25
Training & Learning	120	22
Business/E-Transacts	80	15
Unclassified	50	9
Total	550	100

Field Survey, 2019

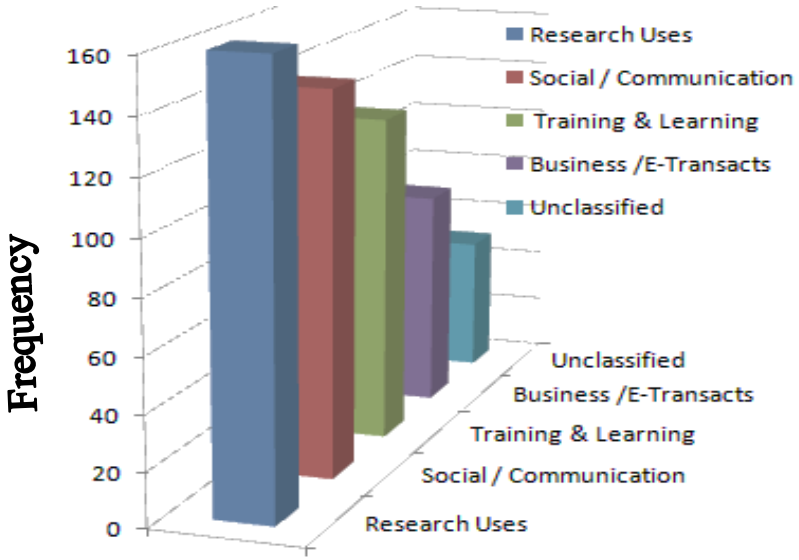

Fig.4: Users demand for Digital Computing Devices

According to the data in Table 5 and Fig. 4 above, 160 respondents (29%) used computers for academic and research purposes, 140 respondents (25%) used them for social and communication purposes, 120 respondents (22%) used them for training and learning, 80 respondents (15%) used them for business, and 50 respondents (9) agreed to use them for unclassified purposes.

USER EXPERIENCE WITH COMPUTER PRIOR TO FRUSTRATING

Table 6: What did you run into at a crucial juncture that prevented you from finishing your task on time?

N=370		
Experience of Frustration	**Frequency**	**Percentage (%)**
Electricity Seizure	140	38
Lack of Internet Access	128	35
Hardware (Input/Output) Failures	18	5
Inadequacies in Digital Proficiencies	8	2
Software Failure	76	20
Total	**370**	**100**

Field Survey, 2019

The information in table 6 gives a clear picture of what is currently occurring in a typical academic environment. It is bothersome that the majority of computers used at work are desktop models with no power backup, necessitating energy/electricity to operate. Waiting for electricity to power the computers caused people to waste a lot of time. In order for academia to participate in an online global platform, internet connectivity is a difficult problem. Table 6 shows that a significant portion (140) of the study's irritating experiences, or 38% of them, were related to power outages. While 35% of the sample as a whole, or 128 respondents, concurred that their frustrations were brought on by problems with no internet access, the other way around. However, 18 respondents, or 5% of the sample, recognized that their annoyances are being brought on by I/O malfunctions in computer hardware. The unsatisfactory computing experience of 8 respondents, or 2% of the sample, was attributed to incompetency or a lack of necessary abilities. Last but not least, 76 respondents (20%) concurred that aspects of their annoying interactions are related to software (Operating System, Applications, File corruption, Virus Attacks, and difficult to locate features). The users' accounts of feeling defeated or resigned are intriguing, suggesting that some users do in fact experience a loss of control when coping with computer troubles.

Important Note: Due to the way those forms were structured and the fact that participants had only one choice, the frequency in table 7 (Female Users) closely equal the total number of frustrating circumstances that were noted. When the two tables are merged, the overall frequency total more than 244 instances of frustrating situations. This is because some participants reported more than one sentiment due to the nature of the data collection method (Male and Female Employee table).

EXPERIENCE AFTER BEING FRUSTRATED

Feeling of Female Computer Users after a Frustrating Experience

In an effort to determine what kind of response was appropriate from the subjects following a computer issue, the subjects were asked to assess their sentiments after the frustrating events.

Table 7: Women Users Share Apprehensive Digital Incidence

N=137		
Feelings	**Frequency**	**Percentage (%)**
Infuriated at the Computer	45	33
Provoked at Yourself	15	11
Concluded to Fix it	23	17
Depressed	34	25
Other	20	15
Total	137	100

Field Survey, 2019

In the survey, 45 (33%) of the frustrating encounters left the user feeling irritated with the computer. There aren't Many Annoying Experiences Due to their self-efficacy and thorough understanding of computing, users reported feeling annoyed at themselves in 15 (11%) and 23 (17%) frustrating experiences. When faced with computer issues, some users do in fact feel as though they have lost control of the situation, as evidenced by the 34 (25%) frustrating experiences that the users reported as discouraging. Meanwhile, 20 (15%) of the respondents said that they had also experienced other frustrating issues.

Computer User Post-Frustrating Experience Feeling in Male Employees

Table 8: Male Employee Users' Post-Frustrating Experience

N=107		
Feeling:	**Frequency**	**Percentage%**
Infuriated at the Computer	51	48
Provoked at Yourself	8	7
Concluded to Fix it	16	15
Discouraged	21	20
Others	11	10
Total:	107	100

According to Table 8 information, 51 (48%) of the study's participants felt angry with the computer as a result of a frustrating experience. Only 8 (7% of the users) said they were frustrated with themselves, while 21 (20%) said they were discouraged, suggesting that some users do indeed feel out of control when dealing with computer issues. Although 16 (or 15%) of the users were determined to fix the problem, 11 (10%) respondents claimed there were further frustrating challenges they had encountered, which may be mediated by the high level of experience mentioned by the subjects.

HYPOTHESIS TESTING

H_1:

i. Digital and knowledge gaps are not the causes of computer user frustration.
ii. The emotional and psychological responses of the user are unaffected by the status of the computer device.

Versus H_o: Not H_1.

Observed Table

Feelings	**Male User**	**Female User**	**Total**
Provoked at the Computer	51	45	96
Infuriated at Yourself	8	15	23
Concluded to Fix it	16	23	39
Disappointed	21	34	55
Others	11	20	31
Total	107	137	244

Source: Field Survey 2019

Expected Table

Feelings	**Male Employees**	**Female Employees**	**Total**
A	E_{11}=107 x 96/244 = 42.098	E_{12}=137 x 96/244 = 53.9	96
B	E_{21}=107 x 23/244 = 10.09	E_{22}=137 x 23/244 = 12.9	23
C	E_{31}=107 x 39/244 = 17.1	E_{32}=137 x 39/244 = 21.9	39
D	$E4_1$=107 x 55/244 = 24.1	E_{42}=137 x 55/244 = 30.9	55
E	E_{51}=107 x 31/244 = 13.6	E_{52}=137 x 31/244 = 17.4	31
Total	**107**	**137**	**244**

RESULT AND DISCUSSION

Test Statistics

$$\sum_{i=1}^{r}\cdot\sum_{j=1}^{c}\frac{(\mathbf{O_{ij}}-\mathbf{e_{ij}})^2}{e_{ij}}\sim \mathbf{X^2_{(r-1)\,(c-1),\,1-\alpha}}$$

$$\frac{(51-42.1)^2}{42.1}+\frac{(8-10.1)^2}{10.1}+\frac{(16-17.1)^2}{17.1}+\frac{(21-24.1)^2}{24.1}+\frac{(11-13.6)^2}{13.6}+\frac{(45-53.9)^2}{53.9}+\frac{(15-12.3)^2}{12.9}+\frac{(23-21.9)^2}{21.9}+\frac{(34-30.9)^2}{30.9}+\frac{(20-17.4)^2}{17.4}$$

=1.88223916 + 0.431453627 +0.071066733 + 0.403304456 + 0.495076284 + 1.470070001 + 0.336974731 + 0.055504674 + 0.314989611 + 0.386665419

= 5.847344696

At 5% level of significance, that is, α=0.05 tabulated Chi Square value.

The degree of freedom α = (5-1) (2-1) = 4

x^2 (2-1) (5-1), 0.95 = x^2_4, 0.95

=9.448

Decision rule: Reject $\mathbf{H_o}$ if X^2 Calculated > X^2 Tabulated.

Decision: Since X^2 Calculated = 5.847344696 is less than X^2 Tabulated (9.448). We will accept $\mathbf{H_o}$.

We can therefore draw the following conclusion:

i. The digital and knowledge divide are the main causes of frustration among computer users.
ii. The state of computer devices affects users' emotional and psychological reactions.

DISCUSSION

This study has investigated the impact of computer user dissatisfaction in the professional setting. The disappointments that have a significant impact on the researchers on a serious note are just one of the study's many significant implications. According to the research's findings, there is a high level of user aggravation with computers and computing technology, and some users do indeed feel out of control while dealing with technical difficulties. Again, the study showed that when significant tasks are delayed and a significant amount of time is lost, the result is that the person becomes frustrated. The negative effects of frustration on computer users' social interactions and health are significant. Two user population categories—female users and male employees—were the subject of the analysis. It makes sense to carry on with this research while concentrating on a specific user group utilizing a well-supported and evidence-based methodology. Users who are younger, have particular traits, are older, are in their second year of high school, have anomalies, etc. will all be taken into consideration by the technique.

ANALYSIS OF RESULTS FROM THE POINT OF VIEW OF THE USER POPULATION

In the analysis of the populations of female and male employee computer users, there were three crucial variables that stood out particularly:

1. How important the current task is.
2. The amount of time required to solve the problem.
3. The time lost throughout the course of the assignment.

This demonstrates that regardless of the user population, the importance of the work and the amount of time lost as a result of the frustrating experience are the biggest sources of annoyance. Higher degrees of frustration were caused by more significant tasks and more time lost. The bad news is that factors like years of computer experience or training have no effect on the level of frustration. Regardless of skill level, male and female computer users will always feel frustrated when a crucial work is delayed for a long period as a result of a frustrating encounter. In all user groups, there was a correlation between the impacted days and the times to remedy them as well as the time lost. Our research showed that, for both female and male users, the amount of time lost because of a frustrating experience affects how the user's day will likely go. However, self-efficacy was not a factor for male users, despite the fact that it is substantially correlated for female users in half of the categories studied. The degree of frustration had an impact on the Female's post-experience attitude and outlook for the remainder of the day. These factors included experience level, aptitude for solving the problem, and tenacity in tackling it. We found that male computer users, irrespective of the user group, show a high level of self-efficacy in managing their frustration with the devices. Compared to women, they can manage digital annoyances with more composure. Male users fretted about their digital difficulties just as much as female employees were anxious about finishing the duties.

CONCLUSION

This analysis was conducted to determine the effect of computer user annoyances. Simple percentage tables, descriptive statistics, and chi-squared hypothesis testing were used to evaluate the data. The study found that some computer users do, in fact, have unpleasant experiences and bad sentiments when things go wrong, which is referred to as frustrations. Analysis revealed that regardless of the user demographic, the importance of the task at the time of interruption and the amount of estimable time lost as a result of whatever the issue was, are the reasonable causes of unpleasant experiences and frustration. The aggravation levels are extremely high for all classes of user population, regardless of personal experience level with computers, when a critical task is stocked in the delayed queue for a decent amount of time as a result of a negative interaction.

RECOMMENDATION

The positive contributions made by contemporary technologies to the development of society and humanity are acknowledged in this study article. As a result, the authors advise further empirical investigation into the effects of the 21st-century computers and computing technology, which are mostly employed in businesses and schools. A different strategy for extending this research, however, is to look at the typical user experiences when using particular kinds of computer apps in addition to other behaviors that were associated with digital usage. In more concrete terms, several studies have looked at what happens when you browse the web, what troubles you have with your operating system, what problems you have when using a spreadsheet program, etc. A well-focused design recommendation can be assessed and possibly realized with the help of such fine-grained research, which will shed light on the precise issues in certain

applications. It is vital to stress that future study needs to focus more on the psychological effects of digital frustrations as well as health difficulties. To create a level playing field in a world where technology is permeating every aspect of life, training, coaching, and support staff services should be utilized efficiently. This will provide a balance to the efficient use of digital computing.

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