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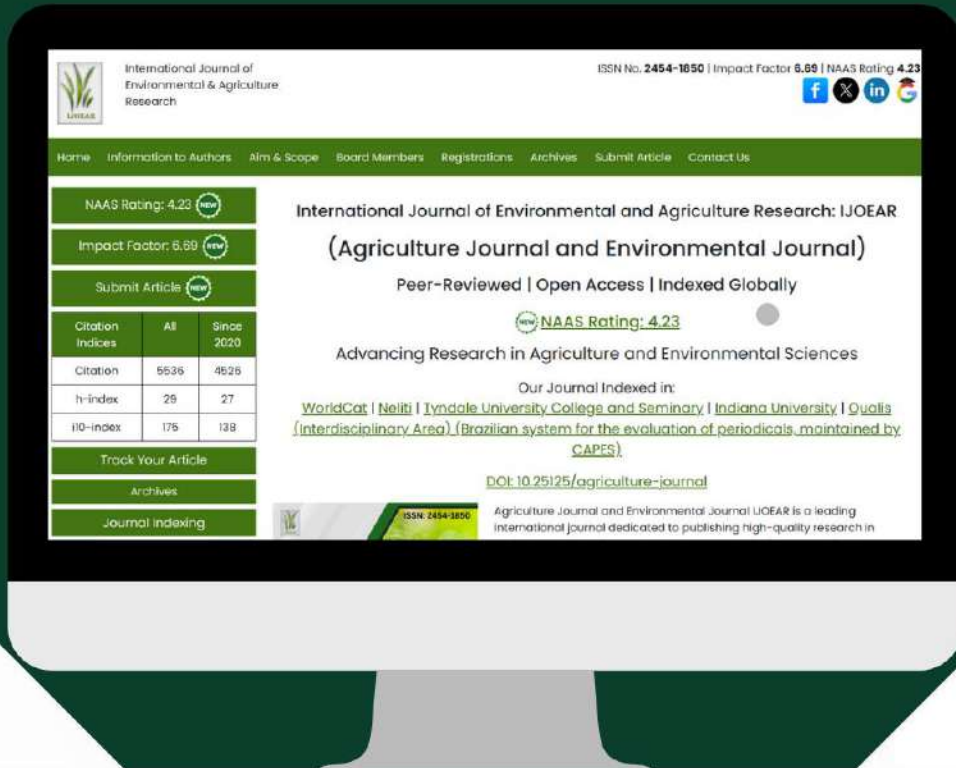

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We would like to present, with great pleasure, the inaugural volume-11, Issue-7, July 2025, of a scholarly journal, *International Journal of Environmental & Agriculture Research*. This journal is part of the AD Publications series *in the field of Environmental & Agriculture Research Development*, and is devoted to the gamut of Environmental & Agriculture issues, from theoretical aspects to application-dependent studies and the validation of emerging technologies.

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

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

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The Effect of Fermented Dragon Fruit Peel Juice on the Performance and Carcass Production of Quails

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Abstract— *This research aims to determine the performance and carcass production of quails that have been given fermented dragon fruit peel juice. The experiment was arranged in a completely randomized design (CRD) using 180 male quails aged 6 to 16 weeks, divided into 3 treatment with 6 replications per treatment and 10 birds per replication unit. The treatments consisted of drinking water without fermented dragon fruit peel juice (FDFJ0), and drinking water supplemented with 4% (FDFJ4) and 6% (FDFJ6) fermented dragon fruit peel juice. The variable observed in this study are growth performance and carcass characteristics. Data were analyzed statistically using analysis of variance (ANOVA) with SPSS for Windows version 23. If significant differences were observed at P<0.05, Duncan's multiple range test was performed for further comparison. The results showed that supplementation with 4% and 6% FDFJ in drinking water significantly increased body weight gain, carcass weight, carcass percentage, breast meat weight, and breast meat percentage, while significantly reducing feed conversion ratio (FCR) compared to the control group (FDFJ0). However, there was no significant effect on feed intake, water intake, final body weight, and slaughter weight. In male quails aged 6-16 weeks, it has been determined that adding 4% and 6% fermented dragon fruit peel juice to drinking water enhances growth performance and carcass quality, especially with regard to breast meat production and FCR.*

Keywords— Carcass Characteristic, Dragron Fruit Peel Juice Fermented, Performance, Quails.

I. INTRODUCTION

Quails are a poultry commodity for meat and egg production that is gaining popularity among the Balinese community. However, raising quail can provide resource for poor families with meet and eggs. The females are very prolific because they begin laying eggs on average at six weeks and in raising male quails, only females are selected to be kept as egg producers, the will selling the male quail to the market to be raised as breeders and marketed in carcass form, as fried quail, roasted quail, quail soup at restaurants and street vendors/Lapak-Lapak.

The widespread use of oral medication in chickens has resulted in the emergence of drug resistance. The application of antibiotics in livestock leads to the risk of transmitting drug-resistant genes to human pathogens (Gould, 2008). The World Health Organization (WHO, 2018) states that the use of antimicrobials in food-producing animals is an important public health risk. To provide an alternative to growth-promoting antibiotics (AGPs), probiotics have been created and added to poultry feed or their drinking water as a promising means of limiting intestinal colonization by disease-causing bacteria. Lately, there's been increasing interest in phytochemicals from dragon fruit peel as a natural substitute for antibiotic growth promoters (AGPs). Numerous plant-based extracts have shown antimicrobial properties and are commonly used in poultry farming to boost productivity (Dewi et al., 2022). Dragon fruit (Hylocereus polyrhizus), which was introduced and cultivated in Indonesia around 2000 (Dewi et al., 2016), produces a peel that is mostly discarded as agricultural waste. In spite of this, the peel's concentration of antioxidants helps shield cells from harm brought on by free radicals and can lessen oxidative stress in fowl that are subjected to environmental stress. According to Daniel et al. (2014), the peel of dragon fruit contains a large amount of crude fiber (23.39%), which limits its direct inclusion in poultry feed. Bidura (2020) recommended utilizing fibrous herbal materials in the form of water extracts or juices, since fiber is insoluble in water. Pamungkas (2011) also noted that the high fiber and low protein content in local agricultural by-products can hinder their use in animal diets. However, fermentation has been suggested as a solution, as it can break down complex organic compounds into simpler, more digestible forms, and improve the taste and aroma, making them more acceptable to animals.

Saccharomyces cerevisiae it has been demonstrated that yeast acts as a probiotic in chickens and improves the digestion of fibrous foods (Bidura et al., 2021; Dewi et al., 2022). The crude fiber content of the feed can be decreased during the yeast fermentation process, improving the birds' ability to use it. According to Tanaka et al. (1992) and cited in Bidura (2020), fermentation products also have the advantage of inhibiting the liver enzyme 3-hydroxy-3-methylglutaryl-CoA reductase, which is involved in the synthesis of cholesterol. There is a lot of potential in using premium Saccharomyces cerevisiae yeast as a supplement. There is currently little research on using dragon fruit peel as animal feed. Dragon fruit peel can be safely added to the diet at levels of up to 1% (Ningsih et al., 2017) or even up to 4% without having a negative impact on the health of the livestock, according to Wardani et al. (2023) and Ningsih et al. (2017). Additionally, it has been demonstrated that supplementing 5-week-old broiler chickens with 4% fermented dragon fruit peel using Saccharomyces cerevisiae enhances their performance. The performance of quails aged 1 to 6 weeks was not considerably improved by fermenting dragon fruit peel with Saccharomyces cerevisiae in drinking water, according to research by Stradivari (2021).

Several studies (Bidura, 2020; Bidura et al., 2021; Dewi et al., 2022; Ningsih et al., 2017; Stradivari, 2021) have reported that adding herbal juices to poultry drinking water can significantly improve performance and egg production, as well as reduce feed conversion ratio. Additionally, such supplementation has been shown to significantly lower cholesterol and fat levels in the body. Based on these findings, the present study investigates the effect of administering either non-fermented or fermented dragon fruit peel juice (FDPJ) through drinking water on the performance and carcass characteristics of quails aged 6 to 16 weeks.

II. MATERIALS AND METHODS

In this study, 160 male quail of the Coturnix coturnix japonica species, all 6 weeks old, and homogeneous body weight had been used. The ration used in the study was the commercial ration QQ 504 S produced by PT Sreeya Sewu Indonesia. The nutrient contents of the ration were: 4% water; Metabolizable energy 2800 Kcal/kg; 14% crude protein; 7% crude fat ;7% crude fiber; 14% ash; 2.5% calcium; 0,6% phosphor; 0,4% methionine and 0,60 methionine +cystine. The equipment used consisted of 18 colony cages, each measuring 70 cm in length, 20 cm in height, and 50 cm in width, along with feed and water containers, and a digital scale.

The research design used a Completely Randomized Design (CRD) which consists of 3 treatments and 6 repetitions. The treatments were based on the tape yeast Saccharomyces cerevisiae for fermented dragon fruit peels juice. The treatments given were: FDFJ0 = Drinking water without fermentation of dragon fruit peels juice; FDFJ4= Drinking water with 4% of fermentation dragon fruit peels juice and FDFJ6= Drinking water with 6% of fermented dragon fruit peels juice. In this study, tape yeast was used to ferment the peel of red dragon fruit (Hylocereus polyrhizus). The dragon fruit peel (DFP) was cut into small pieces, combined with yeast, and kept anaerobically for five days in order to complete the fermentation. Following three days of fermentation, one kilogram of DFP was mixed with one liter of water (1:1 ratio, g/g) until it was smooth, and then it was filtered through double-layer gauze. According to the treatment procedures, the resultant fermented dragon fruit peel juice (FDPJ) was added to drinking water at concentrations of 4 to 6 cc per 100 cc of water (Dewi et al., 2022). FDPJ was added to drinking water continuously for the duration of the study.

Laboratory analysis by Dewi et al. (2022) showed that the phytochemical content of the fermented dragon fruit peel juice included 16.62 mg/100 g flavonoids, antioxidant activity measured at 22.99 mg LGAEAC, and a total population of lactic acid bacteria of 8.1 × 105 in the gut tract. The research was conducted in Megati District, Tabanan, Bali, Indonesia, over a 14-week period, divided into 2 weeks of preparation, 10 weeks of data collection, and 2 weeks of data analysis. The preparation phase involved internal coordination, setting up the research site, preparing infrastructure, livestock conditioning, and feed adaptation. Drinking water, sourced from PDAM, was provided ad libitum. Feed was also given ad libitum from morning until evening. The drinking water treatments consisted of water mixed with either 4% or 6% fermented dragon fruit peel juice.

Performance measures, including feed and water consumption, final body weight, body weight gain, and feed conversion ratio (FCR), as well as carcass weight and percentage, including the weights of the breast, back, thighs, and wings, were among the variables that were observed. Feed intake and individual body weight were recorded weekly. Slaughter weight was determined by weighing live quails at the end of the study after a 12-hour fasting period. Carcass weight was obtained by slaughtering the quails and removing non -carcass components such as feathers, head, neck, internal organs, and both legs. Carcass percentage was then calculated using the following formula:

Carcass percentage = (Carcass weight / Slaughter weight) × 100% (1)

Analysis of variance (ANOVA) was used to examine research data using the Statistical Package for the Social Sciences (SPSS) version 2021. Duncan's Multiple Range Test was used for additional comparison if significant differences between treatments were discovered (P<0.05).

III. RESULTS AND DISCUSSION

3.1 Quail Performance:

The results showed that quails gave treatment FDFJ0, FDFJ4 and FDFJ6 in drinking water give to body weight gain significantly and decreased FCR (p<0.05) (Table 1). The result showed that quail that giving treatment dragon fruit peel juice was able to increase final body weight and body weight gain FDFJ0 were 304.18g/e and 130.80 g/e (Table 1.). Treatment FDFJ4 was 2.6%higher and 2.90% lower no significant different (p>0.05) than FDFJ0 and FDFJ6. But Treatment FDFJ6 was higher 5.48 % significantly different (p<0.05) than treatment FDFJ0. Similar with body weight giant treatment FDFJ6 was 10.80% significantly different (p<0.05) than treatment FDFJ0.

The amount of feed ingested and the nutrients absorbed by the body affect the final body weight and body weight gain of male quails. Higher final body weight is the result of greater tissue development (Ningsih et al., 2022; Stradivari, 2021). Although feed and water consumption were not significantly affected, a significant decrease in feed conversion ratio (FCR) (p<0.05) was observed in male quails treated with 6% fermented dragon fruit peel juice (FDFJ6). Lactic acid bacteria (LAB), a type of gram-positive bacteria that live in quails' digestive tracts and help with nutritional absorption, are responsible for this action. LAB converts carbohydrates into lactic acid (Dewi et al., 2016; Ningsih et al., 2022; Wardani et al., 2023). The average LAB population in the intestines of quails, as described in the Materials and Methods section, was 1.8×10^5 CFU/g. According to Suartiningsih et al. (2018), factors that influence body weight gain include the quantity of feed intake, physical form of the feed, feed composition, and the balance of nutrient content. Numerically, an increase in average body weight gain was observed in quails receiving FDFJ. This improvement is likely due to the antioxidant content of dragon fruit peel juice, which helps neutralize free radicals. Dewi et al. (2022) and Suartiningsih et al. (2018) stated that dragon fruit peel has antioxidant properties and potential as a free radical scavenger. Supplementing livestock diets with antioxidant-rich materials can mitigate the effects of free radicals, which are known to cause oxidative stress (Fig. 1).

TABLE 1
MALE QUAIL CARCASSES AND PERFORMANCE AGED 6-16 WEEKS WERE FED DRINKING WATER CONTAINING FERMENTED DRAGON FRUIT PEEL JUICE (FDFJ)

Variable	Treatment 1			
	FDFJ0	FDFJ4	FDFJ6	SEM$^{3)}$
Animal Performance Initial body wight (g)	173.38	176.68	175.20	0.53
Final body weight (g)	304.18^{b}	312.5^{ab}	321.83$^{a,2)}$	4.20
Body weight gain (g/10 weeks)	130.80^{b}	135.32^{ab}	146.63^{a}	6.33
Feed Consumption (g/10 week)	1,274.00	1,260.00	1,134.00	34.05
Water consumption (ml)	2,675.40^{a}	2,646.00^{a}	2,268.60^{a}	60.85
FCR	9.74^{a}	9.32^{a}	7.73^{b}	1.12
Carcass Yield Slaughter weight(g)	204.17	206,30	221.83	5.53
Carcass weight (g)	116.88^{b}	124.33^{a}	135.58^{a}	1.98
% carcass	57.25	60.27	61.12	1.45
A Part of Carcass Breast (%)	39.90^{b}	40.49^{ab}	43.51^{a}	1.153
Wing (%)	9.25	10.54	8.97	0.067
Tight (%)	20.98	22.40	28.65	0.42
Back (%)	27.21	26.39	26.39	0.67

Note:

1) ***FDFJ0 = Drinking water without fermented dragon fruit peel juice,***
   FDFJ4 = Drinking water with 4% of dragon fruit peels juice and
   FDFJ6= Drinking water with 6% of fermented dragon fruit peel juice.
2) ***The values of the different superscript on the same row show the non-significant differences (P<0.05).***
3) ***SEM: Standard Error of The Treatment Means***

Based on research related to total phenolic content, antioxidant activity, and antiproliferative effects, dragon fruit peel has shown stronger potential in inhibiting cancer cell growth compared to its non-toxic flesh. Extracts of super red dragon fruit peel (Hylocereus costaricensis) using water as a solvent contain anthocyanins at a concentration of 1.1 mg/100 ml (Bidura, 2020; Ningsih et al., 2022).

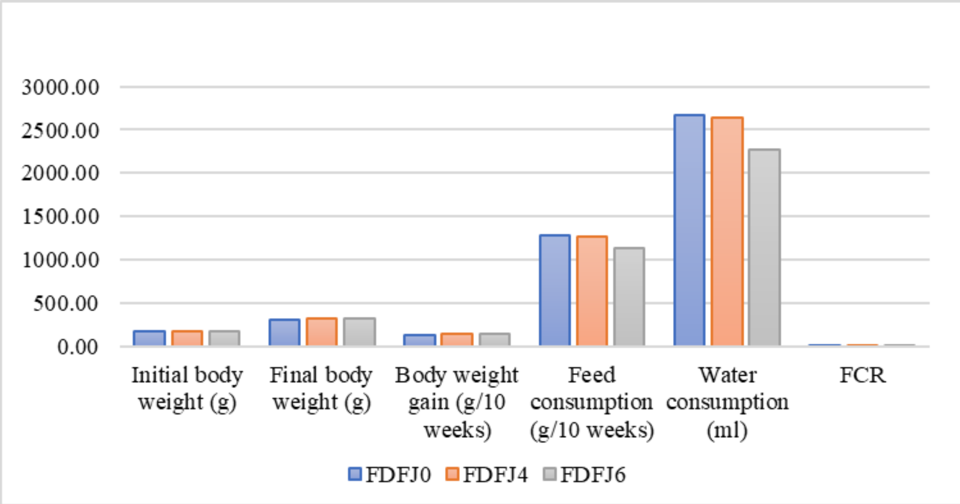

FIGURE 1: The effect of treatment for animal performance

3.2 Cascass Yield:

The results obtained are the addition of with FDFJ4 and FDFJ6 in drinking water give to, carcass weight, carcass and breast percentage, increased significantly (P<0,05) than FDFJ0 treatment. Carcass weight is influenced by the size of external body parts such as the head, neck, thighs, feathers, and blood. The increased carcass weight in male quails receiving the FDFJ6 treatment is likely due to the relatively high antioxidant content found in dragon fruit peel. Studies on total phenolic content, antioxidant activity, and antiproliferative effects have shown that dragon fruit peel is a more potent cancer cell growth inhibitor compared to its non-toxic flesh. Extracts of super red dragon fruit peel (*Hylocereus costaricensis*) using water as a solvent contain anthocyanins at a concentration of 1.1 mg/100 ml (Ningsih et al., 2022; Pamungkas, 2011). The results of this study indicated that carcass weights in the FDFJ0, FDFJ4, and FDFJ6 treatments showed significantly different results (P > 0.05) as presented in Fig. 2.

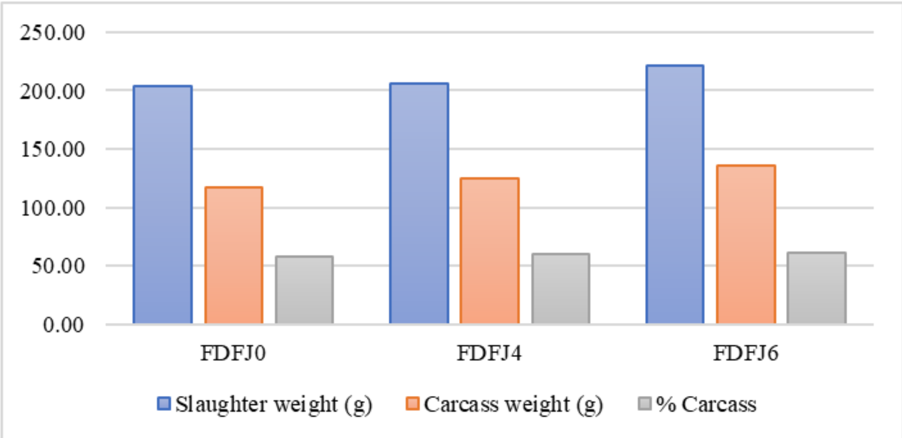

FIGURE 2: The effect of treatment for male quail carcass yield

Based on the results of statistical analysis, administering 6% FDFJ through drinking water can increase the carcass weight of quails. This is attributed to the presence of *Saccharomyces cerevisiae* yeast in the fermented dragon fruit peel juice, which promotes the growth of lactic acid bacteria (LAB) that function as probiotics. These probiotics aid the digestive process, protect, and maintain the health of the digestive tract, thereby contributing to an increase in final body weight and carcass weight. According to Bidura (2020), supplementation of *Saccharomyces cerevisiae* in the diet can significantly enhance growth and improve nutrient digestibility. The addition of lactic acid bacteria to feed through the use of Saccharomyces cerevisiae as a probiotic source has been shown to improve fat absorption and other digestive processes (Bidura, 2020; Dewi et al., 2022; Wardani et al., 2023).

The results indicated that breast meat yield increased with the addition of FDFJ in the drinking water. This improvement is attributed to the antioxidant content in dragon fruit peel, which helps reduce the effects of free radicals, thereby enhancing the animals' immunity and improving hormonal functions. This aligns with the findings of Wardani et al. (2023), who reported that antioxidants support hormonal processes in livestock. Furthermore, dragon fruit is known for its strong anti-radical properties and high antioxidant activity (Dewi et al., 2022; Suartiningsih et al., 2018). Phytochemical analysis of fermented dragon fruit peel juice (as presented in the Materials and Methods section) showed antioxidant activity of 22.9876 mg/L GAEAC. According to Ningsih et al. (2022), Stradivari (2021), and Wardani et al. (2023), antioxidant content in the diet can help maintain carcass quality by preserving mineral levels in the body, as illustrated in Figure 3.

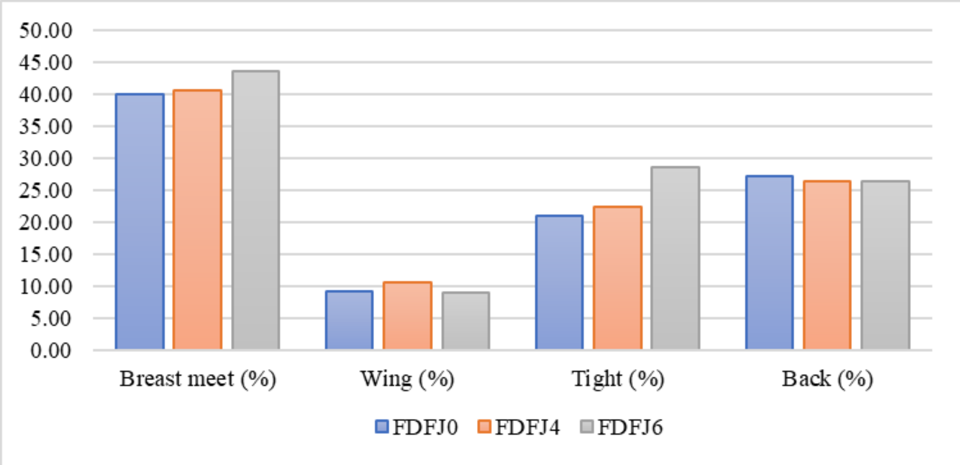

FIGURE 3: The effect of treatment for a part of carcass male quails

The fermentation process, aided by Saccharomyces cerevisiae yeast found in tape yeast, can enhance the population of lactic acid bacteria (LAB) in the digestive tract of quail. According to Dewi et al. (2022) and Stradivari (2021), Saccharomyces cerevisiae acts as a probiotic source in poultry feed, increasing LAB numbers. This increase in LAB through fermentation supports better nutrient absorption and improves the overall health of the animals. Furthermore, Ningsih et al. (2022) and Widodo et al. (2015) reported that the higher carcass portion in quails receiving FDFJ4 and FDFJ6 treatments is attributed to the relatively high antioxidant content in dragon fruit peel.

In conclusion, male quails aged 6 to 16 weeks can benefit from increased body weight gain, carcass weight, carcass and breast meat percentage, and decreased feed conversion ratio (FCR) when given 4% and 6% fermented dragon fruit peel juice through drinking water.

IV. CONCLUSION

The administration of fermented dragon fruit peel juice (FDFJ) in drinking water at concentrations of 4% and 6% significantly improved the growth performance and carcass quality of male quails aged 6 to 16 weeks. The supplementation enhanced final body weight, body weight gain, carcass weight, carcass percentage, and breast meat yield, while also reducing the feed conversion ratio (FCR). However, it did not significantly affect feed and water intake. These improvements are attributed to the antioxidant and probiotic properties of the fermented juice, particularly the presence of *Saccharomyces cerevisiae* and lactic acid bacteria, which enhance gut health and nutrient absorption efficiency.

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Nutritional and Biological Analysis of Nutrient-dense Banana Sap Water

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Abstract— *The analysis of banana sap water (BSW) reveals its significant bioactive properties and potential applications in various fields, particularly in medicine and agriculture. Research indicates that banana sap is rich in antimicrobial compounds, making it a valuable resource for health-related applications. Additionally, its nutrient composition supports plant growth, suggesting its utility in agricultural practices. BSW shows antibacterial activity, and it is more active against Gram-negative bacteria. The absence of a zone of inhibition in the case of antifungal activity indicates, BSW does not show antifungal activity against Aspergillus niger and Aspergillus flavus. BSW contain a considerable amount of N, P, and K along with essential micronutrients like Ca, S, Mg, Mn, Fe, Zn, Cu, B, etc., which play a significant role in plant health and productivity. The nutritional and biological analysis revealed the presence of micronutrients and antibacterial qualities, which broadens its range of applications. The application of bio-enriched banana pseudostem sap as a liquid organic fertilizer (LOF) topically affects nutrient absorption, yield and quality of plants.*

***Keywords—* Banana sap water, antimicrobial, antifungal, nutritional analysis.**

I. INTRODUCTION

Banana pseudostem sap contains essential macro and micronutrients, along with growth-promoting substances like cytokinin. It serves as a cost-effective organic fertilizer, enhancing crop growth and yield, particularly in cowpea cultivation [1]. Banana sap can be utilized as an organic bio-fertilizer, enhancing onion growth and reducing chemical fertilizer dependency, with increasing yield. The sap's nutrient content supports sustainable agricultural practices, making it a valuable resource in farming [2]. Foliar application of enriched banana pseudostem sap significantly improves nutrient uptake in crops like sweet corn and onions, leading to increased yields and quality [3]. Banana sap contains significant compounds such as apigenin glycosides, myricetin glycosides, and dopamine, which are linked to antioxidant and antimicrobial activities. High-performance liquid chromatography analysis has identified these compounds, indicating their potential health benefits [4]. In vitro studies show that unoxidized banana sap has strong antibacterial effects, with minimal inhibitory concentrations. The sap's antioxidant capacity is notable, with a DPPH radical scavenging activity demonstrating significant efficacy. Unoxidized banana sap demonstrates strong antibacterial effects, with minimal inhibitory concentrations against various bacteria and fungi. The sap exhibits notable radical scavenging activity, indicating its potential as an antioxidant. Extracts from banana sap have shown significant cytotoxicity against human breast cancer cells, with a proliferation inhibition rate [5].

LOF can be produced through anaerobic fermentation of banana peels and stems, often using effective microorganisms as bioactivators [6]. Training programs have been implemented to educate communities on producing these fertilizers, enhancing local agricultural practices [7]. Organic fertilizers with biopesticides, addressing both nutrient supply and pest management [8]. Fermented banana pseudostem sap enriched with various ingredients can effectively enhance marigold growth and yield attributes, serving as a sustainable alternative fertilizer [9]. Novel organic liquid fertilizer, along with the recommended dose of fertilizers improves the growth and yield parameters of vegetable crops. These organic formulations can be an effective tool towards the era of organic vegetable farming in the future tenure [10]. BPS can be considered as potential organic fertilizers for 'Sewy' date palms and were able to save 40% of chemical fertilizers [11]. Organic liquid manures are a superior substitute for organic fertilizers and chemicals based on carriers. It could help the soil in a variety of ways [12]. Studies on rats showed improved wound healing when treated with banana sap, attributed to its saponins and flavonoids [13].

The nutritional and biological analysis of nutrient-dense BSW is essential for understanding its potential as a functional food ingredient and therapeutic agent. BSW, a natural byproduct of banana plants, contains high levels of essential nutrients, bioactive compounds, and phytochemicals that may enhance health. Evaluating its nutritional content helps pinpoint vital elements such as vitamins, minerals, antioxidants, and enzymes that benefit metabolic processes and overall health. Moreover, biological assessments, including antimicrobial and antifungal properties, shed light on BSW's possible role in preventing diseases and natural preservation. A thorough analysis of BSW can facilitate its application in nutraceuticals, promote sustainable agriculture, and support alternative medicine, ultimately increasing the value of banana production while minimizing agricultural waste. The present study focuses on the nutritional and biological analysis of BSW.

II. MATERIALS AND METHODS

BSW was extracted from banana pseudostem (*Musa acuminata*) collected from the fields of Ainpur, Jalgaon, Maharashtra, India. The antibacterial activity of BSW was evaluated using the disk diffusion assay against *Escherichia coli, Salmonella typhi (Gram –ve) & Bacillus subtillis, and Staphylococcus aureus (Gram +ve)* bacteria. 0.1 ml bacterial suspension was spread on a sterile nutrient agar plate. A sterile filter paper disk soaked in BSW was placed at the center of the plate. The plate was incubated for 24 hours at 37°C. On the next day, the plate was observed for the occurrence of zone of inhibition around the filter paper disk. The diameter of the zone of inhibition was measured in millimeters.

The antifungal activity of BSW was evaluated using the disk diffusion assay against *Aspergillus niger* and *Aspergillus flavus*. A sterile potato dextrose agar (PDA) plate was uniformly inoculated with a fungal spore suspension. A sterile filter paper disk was impregnated with BSW and placed at the center of the inoculated PDA plate. The plate was incubated at room temperature for 48 hours. After the incubation period, the plate was examined for the occurrence of zone of inhibition surrounding the filter paper disk. The diameter of the zone of inhibition was measured in millimeters.

III. RESULTS AND DISCUSSION

BSW sample was analyzed in the Bioscience Biotech laboratory, Central Govt. Approved AGMARK & ISO9001:2015 certified, Pune and antimicrobial activities were analyzed in department of Zoology, S.V.P Arts and Science College, Ainpur, Maharashtra, India. The results of analysis per 250 ml BSW sample are shown in Table 1.

Nitrogen is essential for vegetative growth and is often diagnosed through leaf analysis, which shows varying levels throughout the plant's life cycle. It plays a crucial role in energy transfer and photosynthesis, with its content fluctuating during different growth phases [14]. While the focus on N, P, and K is essential for optimizing banana production, it is also important to consider the balance of micronutrients and the potential for deficiencies, which can significantly impact plant health and yield [15]. The pH, electrical conductivity, and organic carbon content of banana sap water are critical parameters that influence its utility as a fertilizer and its effects on plant growth. The pH of banana sap water is essential for nutrient availability. A neutral to slightly acidic pH (around 6-7) is generally favorable for nutrient uptake in plants. Maintaining optimal pH levels can enhance the effectiveness of organic fertilizers, such as those derived from banana sap, which can stimulate plant growth and improve soil health. Electrical conductivity (EC) indicates the salinity of the sap water, which affects plant growth. Higher EC values can suggest a higher concentration of dissolved salts, which may be beneficial or detrimental depending on the plant's tolerance. Monitoring EC is crucial for ensuring that the sap water does not lead to salt stress in plants, which can hinder growth and yield. Organic carbon in banana sap water contributes to soil fertility and microbial activity. It serves as a food source for beneficial soil microorganisms, promoting a healthy soil ecosystem. The presence of organic carbon can enhance the soil's water retention capacity and nutrient-holding ability, which is vital for sustainable agricultural practices [16]. Ca ranges from 120-150 mg/L, essential for cell wall structure and stability. Mg, found at 30-40 mg/L, is vital for chlorophyll production. S, Concentration is approximately 45-55 mg/L, important for amino acid synthesis. Mn, Levels of 0.6-1.0 mg/L are noted, crucial for photosynthesis. Fe, Present at 4.0-6.0 mg/L, is necessary for electron transport in plants. Zn, found at 0.3-0.5 mg/L, is important for enzyme function. Cu, Concentration is around 0.03-0.05 mg/L, involved in photosynthesis and respiration. B, typically 0.3-0.5 mg/L, is essential for cell division and growth. The nitrogen concentration in banana sap water is typically around 130-150 mg/L, a Phosphorus level in banana sap water range from 30-40 mg/L, Potassium is found in higher concentrations, approximately 300-360 mg/L [17].

The moisture content in banana sap water is significant for nutrient transport and overall plant hydration, although it is also important to consider that variations in nutrient levels can occur due to environmental factors and fertilization practices, which may influence the overall health and yield of banana crops. The study analyzed macro and micronutrients in banana root sap, finding significant concentrations of Ca and Mg, with Mn and Fe being predominant in fertilized and unfertilized plants, respectively [18]. The mineral composition of banana sap water, including elements such as S, Ca, Mg, Mn, Fe, Zn, Cu, B, and moisture content, is crucial for understanding the nutritional status of banana plants. Research indicates that these elements play significant roles in plant health and productivity.

3.1 Antibacterial activity of BSW:

Banana sap, particularly from the midrib and stem, contains various bioactive compounds such as saponins, flavonoids, and tannins, which contribute to its effectiveness against both bacteria and fungi. The antibacterial and antifungal activity of banana sap water has been extensively studied, revealing its potential as a natural antimicrobial agent. Banana midrib sap demonstrated significant antibacterial activity against Staphylococcus aureus [19]. Extracts from banana plants have shown efficacy against various bacteria, including Enterococcus faecalis and Escherichia coli, due to their rich phytochemical composition [20]. Banana tree sap is effective against Staphylococcus aureus bacteria. Phytochemical test confirms antibacterial properties of banana tree midrib sap. The antibacterial properties of banana tree midrib sap against Staphylococcus aureus, demonstrating its effectiveness at concentrations of 15%, 30%, and 60% [21]. The antimicrobial properties of various banana cultivars' corm, pseudostem, and leaves against selected human pathogens, including bacteria and Candida biofilm, using different solvent extracts. Some cultivars exhibited broad-spectrum activity, inhibiting all tested pathogens [22].

The antibacterial and antifungal properties of banana sap water have been extensively studied, revealing its potential as a natural antimicrobial agent. Research indicates that banana sap, particularly from the midrib and pseudostems, exhibits significant antibacterial activity against various pathogens, including Staphylococcus aureus and Escherichia coli, as well as antifungal effects against Candida albicans. The antibacterial activity of BSW is shown in Table 2.

The above result indicates that BSW shows antibacterial activity and it is more active against Gram-negative bacteria.

3.2 Antifungal activity of BSW:

Saponins extracted from the Amboina banana stem inhibited the growth of Candida albicans, with an average inhibition zone indicating its potential as an antifungal agent. The use of banana extracts may provide an alternative to conventional antifungal treatments [23]. Banana sap demonstrates antibacterial properties; its antifungal activity is less pronounced. Some studies indicate limited effectiveness against fungi like Aspergillus niger [24]. The antifungal activity of BSW is shown in Table 3. (-) indicates the absence of a zone of inhibition.

The above result indicates that BSW does not show antifungal activity against *Aspergillus niger and Aspergillus flavus.*

3.3 Preparation of LOF from BSW:

The use of banana pseudostem sap and turmeric extract as liquid organic fertilizers presents a promising avenue for sustainable agriculture. Research indicates that BSW enhances plant growth, yield, and quality across various crops, while turmeric extract is recognized for its potential bioactive properties. Turmeric, particularly its active compound curcumin, has demonstrated significant insecticidal and pest-repellent properties with significant mortality rates. Higher concentrations of turmeric extract correlate with increased mortality rates in pests [25]. A low-cost organic fertilizer has been developed using underutilized resources, including Palmyrah leaves, coconut leaves, and banana pseudostems, along with Spirulina and Azolla. This initiative aims to mitigate the harmful effects of inorganic fertilizers and contribute to the circular economy by transforming waste into valuable agricultural inputs [26]. Foliar sprays of banana pseudostem sap can enhance the productivity and quality of sweet corn in acidic soil [27]. Apart from the other applications of banana pseudostem [28, 29], BSW can be used as an efficient base in addition to various organic extracts for the preparation of LOF [30]. As BSW contains a considerable number of micronutrients along with antimicrobial properties, it can be effectively mixed with turmeric water extract to prepare LOF for various crops, as shown in fig. 1.

FIGURE 1: Bio-Enriched Lof

TABLE 1
NUTRITIONAL ANALYSIS OF BSW

Sr. No.	Parameters	Unit	Observed Value
1	pH	---	05.75
2	Electric conductivity	μS/cm	06.00
3	Organic Carbon	%	01.11
4	Nitrogen (N)	%	00.39
5	Phosphorus (P)	%	00.46
6	Potassium (K)	%	00.58
7	Sulphur (S)	mg	03.00
8	Calcium (Ca)	mg	05.20
9	Magnesium (Mg)	mg	07.80
10	Manganese (Mn)	mg	01.00
11	Iron (Fe)	mg	02.10
12	Zinc (Zn)	mg	01.08
13	Copper (Cu)	mg	01.50
14	Boron (B)	mg	00.20

TABLE 2
ANTIBACTERIAL ACTIVITY OF BSW

Bacterial Strain	Compound	
	BSW zone diameter (mm)	Positive Control (Azithromycin) zone diameter (mm)
E. coli.	17	34
S. typhi.	10	29
B.Subtilis.	6	23
S. aureus.	7	20

TABLE 3
ANTIFUNGAL ACTIVITY OF BSW

Bacterial Strain	Compound	
	BSW zone diameter (mm)	Positive control (Fluconazole) zone diameter (mm)
A. niger.	-	22
A. flavus.	-	18

IV. CONCLUSION

Based on the findings in the present study, BSW shows antibacterial activity and it is more active against Gram-negative bacteria but it does not show antifungal activity against *Aspergillus niger and Aspergillus flavus.* BSW contain a considerable amount of N, P, and K along with essential micronutrients like Ca, S, Mg, Mn, Fe, Zn, Cu, B, etc., which play a significant role in plant health and productivity. It can be concluded that the nutritional and biological analysis of nutrient-dense BSW is crucial for its use in a variety of applications.

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Sanitizing Waste Water from 12 MW Rice Hull Fired Power Plant by Functional Compound Agents

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Abstract— *Wastewater (WW) produced by a 12 MW Rice Hull Fired Power Plant was analysed and then treated with organic based functional compound agents (FCA) to determine its sanitizing efficacy. Composite samples were analysed for Silica (SiO_2), Nitrates (NO_3^-), Biological Oxygen Demand (BOD), Total Suspended Solids (TSS) and heavy metals specifically lead (Pb) and mercury (Hg) concentration. In-situ properties, namely; pH, temperature, and dissolved oxygen (DO) were also determined by grab sampling. Correlation of these properties with other parameters was done as well.*

Results were compared with the permissible level of the country's environmental regulating body. Exceeding the permissible limit of Class C surface water based on the environmental regulating agency were Pb, temperature, DO, and BOD indicating that the water is slightly unfit for irrigation purposes. Treating the WW ($p < 0.05$) with the FCA resulted in the reduction of pH by 4.6%, in high increase of TSS by 3,315.64% and increase of Pb by 239.62%. Meanwhile, no change was observed in the temperature, DO, NO_3^-, SiO_2 and Hg. Therefore, the FCA tested had no sanitizing effect on the WW.

Keywords— Rice Hull Gasifier Plant, Wastewater, BOD, TSS, Organic Based Functional Compounds, Pb, Hg, SiO_2.

I. INTRODUCTION

Wastewater is produced from rice hull fired power plant which could generate electricity. Water treatment reject, cooling tower blown down, boiler, rain water, cleaning of vehicles and domestic waste are considered as the sources of effluent. Production of steam is an important component of any biomass fired power plant which requires water extracted from deep well ground water. This is done using submersible pump made possible by boring holes to reach the water source. This water resource is often high in mineral content [1] and is treated before using for steam production. Hence, minerals and ions in water must be removed to prevent corrosion of pipes.

Wastewater comes from rejected water during the process of regeneration and cleaning of water treatment plant [2]. Untreated or improperly treated wastewaters are the major sources of surface water body pollution especially when it contains sediments or fly ash. It is one of the most serious environmental problems resulting from industrial, domestic and agricultural activities [3]. Wastewater contaminated with even low concentration of heavy metals or other pollutants may affect the quality of soil, plants, aquatic life and human health. These metals affect soil quality by decreasing microbial processes or activities and may inhibit the physiological metabolism of plants.

Consequently, this condition could become potential threat to human and animal health because of the subsequent accumulation of heavy metals in the food chain [4]. Through the years, series of expensive chemical based treatment technologies have been developed for wastewaters but there is a dearth in the use of non-chemical and organic based treatment strategies. As such, this investigation explored the use of FCA to sanitize wastewater from a 12 MW Rice Hull Gasifier Plant in the Philippines.

FCA was constituted using the following: 7 bacteria for decomposition, enzyme production and nutrient transformation; 3 bacteria for decomposition of polysaccharides and enzyme production; 3 bacteria for enhanced decomposition, compost "Sweetening" and probiotics production; 5 bacteria for nitrogen fixation; 7 fungi composting microbes; aerobic and unaerobic methane producing bacteria; sulfate and ammonia consuming and heavy metal binding bacteria and emulsifiers.

II. METHODOLOGY

Wastewater samples were collected in three sampling stations from the open canal of the 12 MW rice hull fired power plant. Each sample had three replicates. Grab sampling was done for the in-situ parameters such as temperature, pH and dissolved oxygen (DO). Composite sampling was performed for biochemical oxygen demand (BOD), total suspended solids (TSS), silica (SiO_2), nitrates (NO_3^-), lead (Pb^{+2}) and mercury (Hg^{+2}).

A pole sampler was used in some inaccessible sites of the sampling station, which is a continuously flowing drainage canal for wastewater. Sample volumes collected ranged from 500 to 1000 ml. Immediate analysis was done for pH, DO and temperature because its values change quickly. Electrodes of pH and DO meter were immersed to a depth of 3 cm and at least 1 cm away from the sides and the bottom of a beaker. The wastewater samples were stirred gently to establish equilibrium between electrode and sample, to ensure homogeneity, and to minimize carbon dioxide entrapment. The pH level and DO concentration were recorded when the readings had become stable.

Before proceeding to another sample for analysis, the electrode was withdrawn gently and rinsed gently into a beaker with distilled water and was blotted with soft tissue. Container pre-treatment, maximum holding time, sample size, sampling method, preservation and storage were strictly followed in the collection and treatment of samples.

FIGURE 1: Open Canal of GIFT Corporation in Bacal II, Talavera, Nueva Ecija, Philippines (Photo credit from Google Earth 2018)

2.1 Collection and Analysis of Waste Water Samples:

Wastewater samples were collected in three sampling stations from the open canal of rice hull fired power plant. Grab sampling was done for *in-situ* parameters such as temperature, pH and dissolved oxygen. Each parameter had three replicates. DO meter was utilized to measure the dissolved oxygen concentration and temperature level while pH meter was used to determine the pH level. Composite sampling was performed for biochemical oxygen demand (BOD), total suspended solids (TSS), silica

(SiO_2), nitrates (NO_3^-), lead (Pb^{+2}) and mercury (Hg^{+2}) . These parameters were analyzed in the TransWorld Laboratory Incorporated. Requirements in the collection and methods of analysis used are indicated in Table 1.

TABLE 1
SUMMARY REQUIREMENTS IN THE COLLECTION AND ANALYSIS OF SAMPLES

Parameters	Container	Sample Size (mL)	Maximum Holding Time	Methods of Analysis
BOD	Plastic (polyethylene)	200	6 hr	5-BOD Test Azide Modification
TSS	Plastic (polyethylene)	200	7 days	Gravimetric
Silica	Plastic (polyethylene)	200	28 days	Molybdosilicate
Nitrates (NO_3^-)	Plastic (polyethylene)	100	2 days	Cadmium Reduction
Lead	Glass	100	6 months	Wet Digestion & AAS
Total Mercury	Teflon/ Glass	200	6 months	AAS Cold Vapor

Source: Standard Methods for Examination of Water and Wastewater 20th Edition (1998) and laboratory protocol.

2.2 Statistical Analysis:

The experiment was carried out using Completely Randomized Design and comparison among means using t-test. The probability level for significance was ≤ 0.05. Furthermore, Pearson's Correlation Coefficient was used to correlate the different *in-situ* factors while Post-hoc analysis using Tukey's HSD determined the significant difference among the sampling points.

III. RESULTS AND DISCUSSION

3.1 Concentration of the Physico-chemical Parameters before the Addition of FCA:

Differences in concentration of the physico-chemical parameters were determined before and after the addition of the FCA (Figure 2). Also, temperature, pH, and dissolved oxygen of the wastewater were taken from different sampling points before the addition of FCA. The recorded water temperature ranged from 31.77°C to 34.53°C. Sampling Point 3 obtained the highest mean temperature while Sampling Point 1 recorded the lowest mean temperature. This observed range of water temperature surpassed the permissible limit of Class C water body; that is 25^0C- 31^0C. Hence, it could become problematic in the long run when using these surface water bodies. The increasing rate of wastewater temperature from Sampling Point 1 to Sampling Point 3 might be due to the boiling process of the power plant and the exposure of the wastewater to direct sunlight. This result conformed to the results of an earlier study [5].

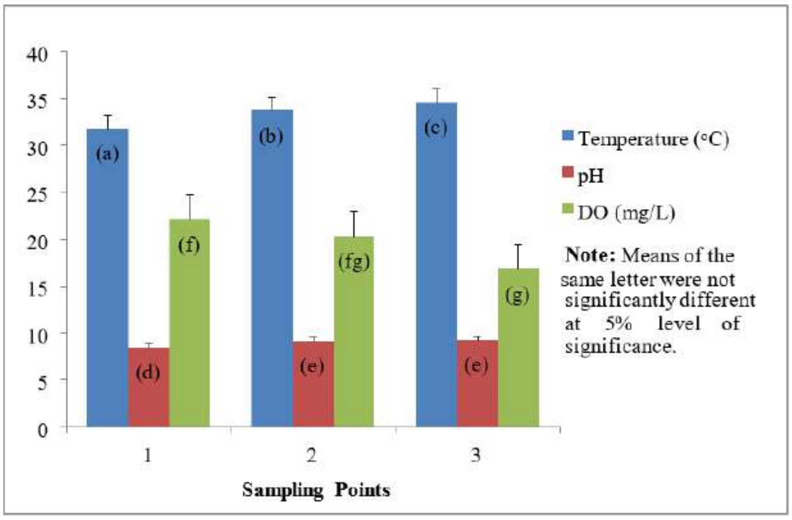

FIGURE 2: Variations in the level of temperature, pH, and dissolved oxygen of wastewater from different sampling points before the addition of FCA

Meanwhile, the pH values of the wastewater ranged from 8.40 to 9.20, which indicated slight alkalinity, thereby safe for irrigation purposes as it is within the national allowable limit. However, Sampling Points 2 and 3 surpassed the permissible limit of 6.59 set by DAO 08-2016. Todd (1980) as cited [1] and Todd and Mays as cited in [6] claimed that the basicity of wastewater could be due to the extracted groundwater as main source for steam production which is often high in mineral content or dissolved salts such as calcium (Ca^{+2}), magnesium (Mg^{+2}), and sodium (Na^{+}). Moreover, preliminary water treatment reject contains these metal ions and is considered as one of the sources of wastewater in a power plant [2].

Data showed that the level of dissolved oxygen (DO) of wastewater varied across the sampling points. Recorded level ranged from 16.77 mg/L to 22.03 mg/L (Figure 5) which was above the national permissible level of 5 mg/L provided by DAO 08-2016 for class C surface water. The lowest reading for dissolved oxygen was recorded in Station 3 while Station 1 recorded the highest reading. According to Metcalf and Eddy (2003) and EPA (1996) as cited [7], DO is required for the respiration of all aerobic life forms in water and its quantity can be governed by temperature, solubility, atmospheric pressure, and concentration of impurities like salinity and suspended solids. Very high and abrupt changes in DO concentration can also be harmful to aquatic life specifically by inducing stress that subsequently makes fish more susceptible to disease. This was confirmed in the study done by Yilmaz (2014) [8].

The concentration of the parameters in Figure 3 was assessed without the addition of FCA. Composite sampling of wastewater samples was done for the analysis. TransWorld Laboratory Inc. started to analyze the samples five days after collection. Analysis for nitrates, BOD, TSS, and silica was performed on April 11-18, 2018. Composite sample was sub-divided into three replications. Each parameter concentration was compared to the national permissible limit set by DAO 08-2016.

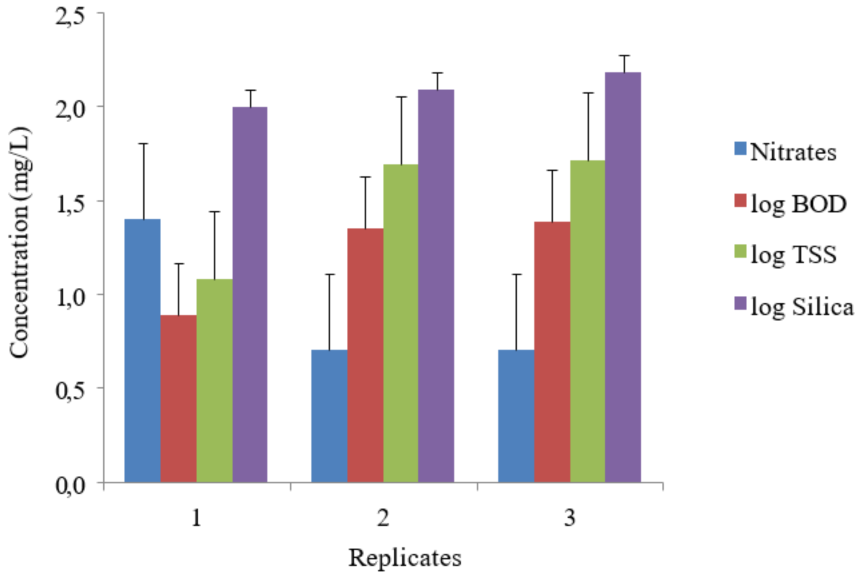

FIGURE 3: Concentration of the different physico-chemical properties before the addition of FCA. Data and deviation are presented with three replications and expressed in mg/L. Most parameters are plotted on a logarithm scale base 10.

Nitrate concentration of wastewater without FCA in the three replications recorded a range of 0.7 mg/L to 1.4 mg/L. This nitrate level in the wastewater was lower than 7 mg/L, the national standard limit set by DAO 08-2016. This is not risky to the aquatic organisms found in the water body. Stendahl (1990) and Liu (1999) were cited [9] as having asserted that the amount of nitrate on wastewater depends on the availability of oxygen for oxidizing bacteria and ammonia to nitrate.

Biochemical oxygen demand (BOD) value of wastewater was recorded as above 7 mg/L, the recommended limit for BOD of class C surface water provided by DENR. This concentration means the wastewater had high content of organic matter. Accordingly [10], the amount of BOD depends on the amount of organic matter and the activity of the bacterial species present in wastewater.

Total suspended solids (TSS) are the solids in the water retained by the filter [11]. The recorded values were within the permissible level at 80 mg/L set by DAO 08-2016. The concentration of all the particles suspended in the wastewater ranged from 12 mg/L to 52 mg/L as shown in Figure 3. This result indicated that the wastewater appearance was clear to cloudy.

In terms of silica concentration, it ranged from 99.2 mg/L to 152.4 mg/L. Its national allowable level was not yet available in the general effluent guidelines by DENR. However, according to the available data in the power plant, 85 mg/L of silica in wastewater was the basis of allowable level. This concentration might be due to the amount of silica present in the rice husk fly ash that mixed with the water [12] and in the extracted groundwater [13].

3.2 Correlations between Temperature and the other Parameters:

Table 2 reveals a highly significant relationship between temperature and the other parameters tested. This means that temperature can influence the rate of pH and DO. Results showed that temperature and DO had a negative substantial correlation in which as temperature increased, the DO decreased and vice versa, confirming the results of previous similar studies [9-14].

Also, temperature and pH showed strong but negative correlation wherein as the temperature increased, the pH level rapidly decreased and vice versa. This result supported the data gathered in a previous study [15]. Similarly, pH was inversely proportional to temperature as stated in Le Chatelier's Principle. This was confirmed by a previous study [16] in which it showed that as temperature level increased, more molecular vibrations or dissociation of hydrogen ions were formed, thereby eventually decreasing the tendency of forming hydrogen bonds and causing a decrease in the pH value of water.

In contrast, DO and pH were strongly correlated to each other positively. Similar result was revealed by a previous study [17] wherein both values of DO and pH rapidly increased or decreased.

TABLE 2
PEARSON CORRELATION OF EACH *IN-SITU* PARAMETERS

Correlation Coefficient Parameters	Temperature	Dissolved Oxygen	pH Values
Temperature		-0.866*	-0.937*
Dissolved Oxygen	-0.866*		0.922*
pH Values	-0.937*	0.922*	

Correlation Scale: 0.01 – 0.20 = very weak 0.41 – 0.70 = moderate
0.21 – 0.40 = weak 0.71 – 0.90 = substantial
0.91– 0.99 = strong

3.3 Heavy Metal Concentrations in the Wastewater:

The data on heavy metals concentration (Figure 4) were analyzed from April 13 to May 2, 2018 by Transworld Lab Inc. Accordingly [18], the presence of such inorganic contaminants in water specifically lead and mercury could pose deleterious effect in the environment. Studies conducted [19,20,21] showed that accumulation in the soil and in the plant of these given elements may occur. In addition, it was revealed [22] that physical factors such as temperature and biological factors such as species characteristics, biochemical/physiological adaptation and trophic interactions can influence the bioavailability of heavy metals.

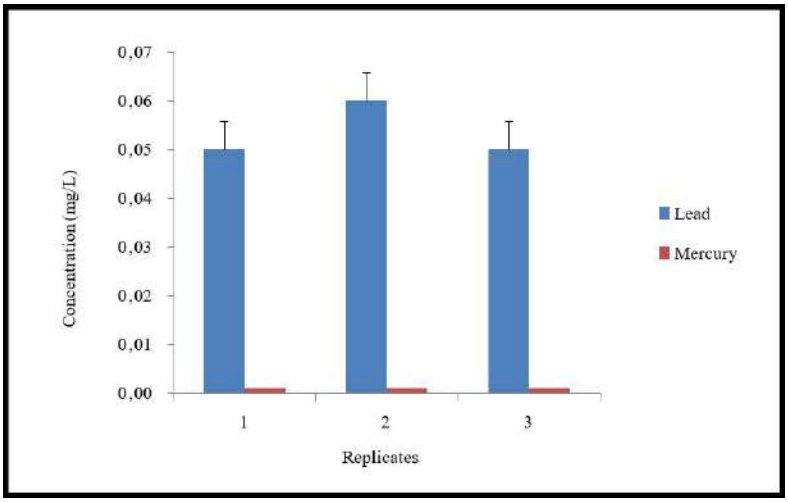

FIGURE 4: Concentration of heavy metals in wastewater before the addition of FCA Data and standard deviation are presented with three replications

The concentration of lead in industrial wastewater limit is 1.0 mg/L according to the Environmental Protection Agency (EPA 2002) while the maximum permissible limit of lead in inland surface water is 0.1 mg/L as set by CPCB. In this investigation, the concentration of lead in the wastewater ranged from 0.05 mg/L to 0.06 mg/L, which is way below the EPA standard for industrial water and CPCB maximum permissible limit of lead in inland surface. This concentration might have been caused by the exhaust from automobiles [23] and additives in gasoline, burning, and factory chimneys [24]. Meanwhile, mercury, a non-essential element, had recorded concentration of 0.001 mg/L which was lower than 0.002 mg/L, the national permissible level provided by the DAO 08-2016.

It was claimed [4] that high or even low concentration of heavy metals may affect the natural soil quality, aquatic life, plants and human health. Heavy metals affect the soil quality by decreasing microbial processes or activities, and may inhibit the physiological metabolism of plants. Eventually, potential threat to human and animal health may occur due to uptake of heavy metals by the plants and subsequent accumulation in the food chain (Schickler and Hadar, 1999) as cited [4]-[28].

3.4 Comparative Concentration of the different Parameters before and after FCA Application:

The comparison on the concentration of the different physico-chemical parameters before and after the addition of FCA (Table 3) revealed a statistically significant difference in pH, TSS and lead across the treatments. The pH values decreased by 4.6% while the total suspended solid abruptly increased by as high as 3,315.64%. Lead increased to 239.62%. These results imply that the FCA failed to sanitize the wastewater, specifically binding the heavy metals present in the wastewater.

TABLE 3
EFFICACY OF FUNCTIONAL COMPOUND AGENT (FCA) IN TREATING WASTEWATER IN 12 MW RICE HULL FIRED POWER PLANT

Elements	Initial Readings	Final Readings	Difference	Significance	% Change
Temperature	33.31	37.41	4.10	0.063^{ns}	12.31
pH	8.91	8.50	0.41	0.003*.	-4.6
DO	19.69	16.84	-2.85	0.868^{ns}	-14.47
Nitrates	0.93	3.67	2.74	0.405^{ns}	294.62
BOD	18.10	203.53	185.43	0.093^{ns}	1,024.48
TSS	37.67	1286.67	1249	0.030*	3,315.64
Silica	124.67	124.93	0.26	0.706^{ns}	0.21
Lead	0.053	0.18	0.127	0.000*	239.62
Mercury	0.001	0.0018	0.0008	0.117^{ns}	80

Note: * significant at 5% level of significance using t-test.

IV. CONCLUSIONS AND RECOMMENDATION

The FCA was effective in reducing the pH and dissolved oxygen level while inefficient in reducing the temperature level, amount of BOD, TSS, silica, nitrate, lead and mercury. The possible increase in heavy metals in the wastewater, particularly “lead”, could have been due to the proximity of the rice hull fired plant (being adjacent) to a paddy field where inorganic fertilizers and insecticides are being applied. The rice hull gasifier fired plant continuously extract groundwater that serves as cooling agent and can be reprocessed to be a part of the wastewater.

Nevertheless, these results can serve as precautionary measure to minimize the potential risk to the environment. The apparently alarming concentration of pollutants, particularly the heavy metals, could result in the deterioration of nutrient soil quality and bio-accumulation by the plants thereby rendering serious environmental problems.

Moreover, the wastewater quality parameters documented may serve as benchmark data in predicting the cumulative toxicity it would bring to nearby vegetation over a certain period, through algorithm equations. More research efforts should therefore be done on other similar or modified FCA to make it an effective sanitizing agent for wastewater from Rice Hull Fired Power plants considering their growing use globally and long term adverse effects to the environment, humans, and animals.

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Assessment of Polycyclic Aromatic Hydrocarbons in Fruits of *Citrus sinensis* (*Porcher Michel H.*) around Port Harcourt Metropolis Nigeria

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Abstract**—** *This study was conducted to assess the polycyclic aromatic hydrocarbons in fruits of Citrus sinensis Collected from trees grown around Port Harcourt Metropolis. Stratified random sampling technique was used to select five study locations grouped into high and low traffic density areas and data collected in the wet and dry seasons. In the dry season higher Concentration of Naphthalene (4.98 x 10^{-5}ppm) was measured at Garrison, acenaphthene at Trans-Amadi (8.28 x10^{-3} ppm), anthracene 6.05 x10^{-5} ppm) at Rivers State University. PAHs measured around the study locations in the dry season were significantly different at $P \leq 0.05$ using the Duncan Multiple Range Test (DMRT). In the wet season, Rivers State University recorded significantly high concentration of Pyrene (7.99 x10^{-4}), Benzo (b) fluoranthene (1.58 x10^{-4} ppm), Benzo (k) fluoranthene (8.63 x10^{-4} ppm), Benzo (a) Pyrene (2.44 x10^{-4} ppm) and Dibenz (a,h) anthracene (3.01 x10^{-3} ppm). Individual PAHs in Rumuokoro were all below detectable limits in the wet season. Rivers State University recorded significantly high concentrations of Benzo (a) Pyrene in both wet and dry seasons. Acenaphthene was detected only at Rivers State University (2.96 x 10^{-3} ppm) in the wet season while anthracene was detected at two locations (Garrison: 1.72 x10^{-5} ppm and RSU:5.33 x10^{-6} ppm). Trans Amadi recorded the highest concentrations of Flouranthene (1.46 x 10^{-4} ppm), Benz (a) anthracene (1.05 x 10^{-5} ppm), Chrysene (4.78 x 10^{-4} ppm), Benzo (b) fluoranthene (7.91 x 10^{-5} ppm), Benzo (k) fluoranthene (3.29 x 10^{-4} ppm), Dibenz (a,h) anthracene (4.64 x 10^{-4} ppm), Indeno (1,2,3-cd) pyrene (1.71 x 10^{-3} ppm) and Benzo (g, h, i) perylene (8.34 x 10^{-4} ppm) in the wet season. In the dry season, Benzo (a)anthracene was observed to be within USEPA standard at the Garrison location. Carcinogenic and mutagenic polycyclic aromatic hydrocarbons such as Benz (a)anthracene and Benz (a) pyrene were observed to have concentrations higher than the USEPA standard in Rivers State University in the wet season, this poses serious threat to humans and other life forms at that location. The distribution of PAHs in fruits within Port Harcourt Metropolis should be monitored regularly due to the toxicological effect and widespread presence in the environment. Government and other relevant authorities should sensitize the public regularly on the sources and health implications of exposure to PAH.*

Keywords**— Fruits, PAH, Port Harcourt metropolis, Citrus sinensis.***

I. INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs) are chemical compounds containing only hydrogen and carbon in multiple aromatic rings. PAHs occurs naturally in coal, crude oil and gasoline, the simplest are the two aromatic rings and the three rings naphthalene, anthracene and phenanthrene (Abdel-shafy and Mansour, 2016). PAHs can originate from natural sources, such as forest fires and volcanic emissions, and also from anthropogenic sources such as coal burning, vehicular emissions, engine lubricating oils, and cigarette smoke (Kim, *et al.,* 2013). Pyrolytic processes are the major sources of PAHs through anthropogenic activities such as combustion of natural gas, incomplete combustion of organic materials, processing of crude oil and coal, combustion of refuse, vehicle emissions, cooking and tobacco smoking (Abdel-shafy, and Mansour, 2016). PAHs generated from various sources accumulate in the environment and enters the food chain through affected water, air, and soil (Karishma, *et al,* 2018).

PAHs from several pyrolytic sources gets into the environment through the air and could be inhaled directly by human (Superfund Research Program-SRP, 2013). PAHs in the air could be transformed, degraded, or deposited. Deposition could be on vegetation, animals, humans, aquatic environment and even soil (Lee and Vu, 2010). PAHs in soil are mostly from atmospheric deposition from pyrolytic sources and from petrogenic sources such as the release of petroleum or crude oil from natural oil seeps and spillage (Obayori and Salaam, 2010).

Polycyclic aromatic hydrocarbons are ubiquitous in nature and are of environmental concern (WHO, 2003). Several PAHs have been identified as potent human carcinogens and persists in the environment (Lee and Vu, 2010). Recent epidemiological studies with humans and animals have indicated that the increasing cancer prevalence can be partly attributed to PAHs exposure. Furthermore, other epidemiological studies have demonstrated that a large proportion of cancer cases may be ascribed to at least in part dietary factors, including dietary exposure to PAHs (Abid, *et al*, 2014).

PAHs concentrations in urban soil are considered to be higher than PAHs in rural soils due to increased vehicular and industrial activities in the urban areas (EFCSG, 2010). However, most oil exploitation and exploration activities usually occur in the rural areas causing accidental or intentional spillage and could also increase PAHs in soil from petrogenic sources in addition to pyrolytic sources in the rural area. Simbi-Wellington and Ideriah, (2022) reported that sixteen individual PAHs were detected in mangrove soil around at oil exploration site in a rural community in Rivers State. Studies have revealed that the concentrations of PAHs in the wet season could be more than that in dry season (EFCSG, 2010). This could be attributed to the absence of sunlight to break down the PAHs through photodecomposition and the probable increase in burning to warm homes. However, observations have shown that more fire incidence or outbreak are likely to occur in the dry season than in the wet season and could likely increase the amount of heating emission and probably PAHs in the environment. Simbi-Wellington and Ideriah, (2022) reported, PAHs were significantly higher in leave samples collected in the wet season month of September and lowest in the dry season month of March.

PAH have been detected in various food such as fruits, leaves, vegetable oil, meat smoked fish, tea and coffee (Lee and Vu, 2010). Absorption of PAHs in fruit can occur through air or soil during the process of cultivation, and prior to consumption through the process of storage and transportation (Alice *et al*., 2017). PAHs in fruit are mainly due to deposition of airborne particulate on exposed surface, the waxy surface of fruit assimilate low molecular mass PAHs through surface absorption and particle bond. According to Alice *et al* (2017) trace level of PAHs such as fluoranthene, pyrene and phenanthrene have been detected in every raw fruit while high concentration of lighter PAHs such as naphthalene have been detected in some fruits.

Low concentrations (0.001 – 0.5 µg kg^{-1} wet weight) of PAHs can be detected in raw fruits, however, research have revealed that concentrations exceeding 0.5 µg kg^{-1} and up to 5 µg kg^{-1} wet weight can be found in several fruits depending on factors such as air quality around the farm site, the crop itself and the specific PAH. Alice *et al.,* (2017) reported that PAHs concentration in fruits is usually higher for crops grown near roadways or in urban regions than in rural areas. Low temperature combustion such as wood burning and tobacco smoking tend to generate low molecular weight PAHs while high temperature industrial processes typically generate PAHs with higher molecular weight (Rose *et al.*, 2015).

Studies have revealed that PAHs can be detected in fruits and leafy vegetables particularly in industrialized cities. According to reports, volatilized PAHs in air is a major contributor of PAH in plants. Ideriah *et al.* (2012) reported a high correlation between pollutants in air and total hydrocarbons in leaves collected around selected farms in Port Harcourt. Several of the PAH compounds have been identified by WHO as carcinogenic and/or mutagenic and poses threat to human health. Port Harcourt being the capital and major city of Rivers State with rapid urbanization and an associated growth in industries and automobiles has been reported to have high levels of hydrocarbons in leaves (Ideriah, *et al.,* 2011). This study aims at providing information on the levels of PAHs in fruits of *Citrus sinensis* grown around Port Harcourt metropolis in the dry and wet season months as PAHs in fruits can act as an indicator of human exposure through consumption.

II. MATERIALS AND METHODS

2.1 Study Location:

Port Harcourt is a highly industrialized city in Nigeria and a major industrial center with a large number of multinational firms as well as other industrial concern and businesses related to the petroleum industry. Port-Harcourt lies within latitudes 4º43 and 4°54N and longitudes 6056 and 7°03 E, 18 meters (59 feet) above sea level with a mean annual rainfall of over 2000mm and mean annual temperature of about 29°C (Nigeria Meteorological Services (NMS), 1998). Port-Harcourt city covers an area of 186km^2 (71.8sq ml) with a land area of 170km^2 (65.6sqmi), and Water area of 16km^2 (6.2sqmi) (Alagoa and Derefaka, 2002). The main city of Port Harcourt is the Port-Harcourt town in the Port Harcourt City Local Government Area, consisting of the former European quarters now called Old Government Reservation Area (GRA) and new layout areas. The Port Harcourt Urban Area (Port Harcourt metropolis) is made up of the city itself and parts of Obio/Akpor Local Government Area. Important neighboring towns are Diobu which is a Rebisi settlement, Abuloma which is an Okrika settlement, Woji which is an Ikwere settlement, Alesa Eleme which is an Ogoni settlement and many other lkwerre clans. All these settlements are collectively known as Greater Port Harcourt. Some of Port-Harcourt's more popular and well-known residential areas are the Port-Harcourt Township also known as Town, G.R.A phases 1-5. Abuloma, Amadi-Ama, and Borikiri. The main industrial area is located at Trans Amadi (Alagoa and Derefaka, 2002; GPHCDA, 2011).

2.2 Site Selection and Sample Collection:

The systematic sampling design was used in the selection of the sampling stations. The criteria used in selection of sampling stations was based on traffic density: high density (>500,000 vehicle per day) and low density (<500,000 vehicle per day). The vehicles at the stations included trailers, trucks, cars, tankers, tractors, tricycles, and motorcycles. A total of five stations were selected for this study.

Fruits samples were randomly collected in the wet and dry seasons from *Citrus sinensis* trees in three replications at each of the study stations with the use of garden scissor and were carefully placed into well labelled polyethylene bags. Collected samples were taken to the laboratory for PAH analysis.

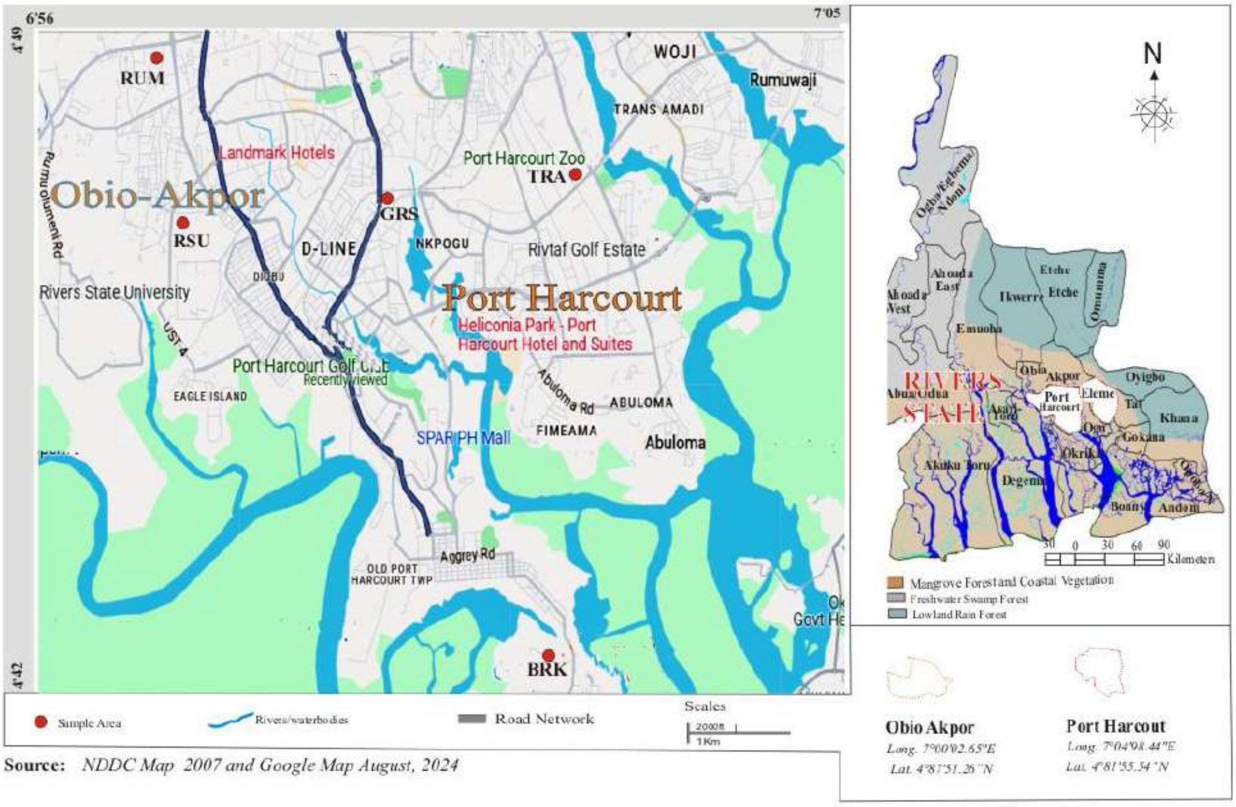

FIGURE 1: Map of Port Harcourt Showing Study Locations

2.3 Determination of Polycyclic Aromatic Hydrocarbons in Fruits:

Polycyclic aromatic hydrocarbons in fruit samples were determined using Gas Chromatograph with Flame Ionization Detector (GC-FID). Ten milliliter of extraction solvent (hexane) were added to 2g of collected samples, mixed thoroughly, allowed to settle filtered using Buchner funnel. Extracts were concentrated to 2m1 and were transferred for clean-up and separation. Thereafter, concentrated aromatic fractions of samples were transferred into glass vials with Teflon and rubber crimp caps for GC analysis. 1µL of the concentrated samples were injected by means of hypodermic syringe through rubber septum into columns of Gas Chromatograph (HP 5890 series 11) Separation occurred as the vapour constituents were partitioned between the gas and liquid phase. The constituent aromatic compounds were automatically detected at emergence from the column by the Flame Ionization Detector (FID).

III. RESULTS AND DISCUSSION

3.1 Dry Season PAHs in Fruits of *Citrus sinensis* Grown around Port Harcourt Metropolis:

Fourteen individual PAHs were detected in fruits of *Citrus sinensis* around Port Harcourt metropolis in the dry season. PAHs detected were Naphthalene, Acenaphthylene, Fluorene, Anthracene, Flouranthene, Benzo (g, h, i), Pyrene, Benz (a) anthracene, Chrysene, Benzo (b) fluoranthene, Benzo (k) fluoranthene, Benzo (a) Pyrene, Dibenz (a,h) anthracene and Indeno (1,2,3-cd) pyrene (Table 1). Total PAH concentrations ranged from 0.00368ppm observed in fruits collected at location RUM to 0.00815ppm observed in fruits collected at location TRA (Fig 2). Table 1 shows that the individual PAHs measured around the study locations in the dry season were significantly different at P≤0.05 using the Duncan Multiple Range Test (DMRT). Concentrations of Naphthalene was highest in locations GAR and RUM (4.98 x10^{-5}ppm and3.65 x10^{5} ppm respectively) and below detectable limit in location BRK, RSU and TRA. Flouranthene was highest in location TRA (5.41 x10^{-5} ppm) and GAR (5.62 x10^{-5} ppm) and lowest in location RSU (below detectable limit). Anthracene was detected only in location RSU (6.05 x10^{-5} ppm), Acenaphthylene in only location TRA (8.28 x10^{-3} ppm) and Fluorene in only location BRK (2.641 x10^{-5} ppm).

Concentrations of Benz (a) anthracene (2.76 x10^{-4} ppm) and Benzo (a) Pyrene (2.44 x10^{-4} ppm) observed at location RSU were above the United States Environmental Protection Agency (USEPA, 2013) recommended limits of 1.0x10^{-4} and 2.0x10^{-4} respectively (Table 2), and therefore poses serious threat to human and other life forms within and around the study locations. PAHs such as pyrene, acenaphthylene, fluorene, anthracene, pyrene, benz[a]anthracene, benzo[k]fluoranthene, benzo[a]pyrene, indeno (1,2,3-cd) pyrene, benzo[b]fluoranthene, fluoranthene and chrysene observed in collected samples are listed as carcinogenic and mutagenic by United States Environmental Protection Agency (USEPA, 2013).

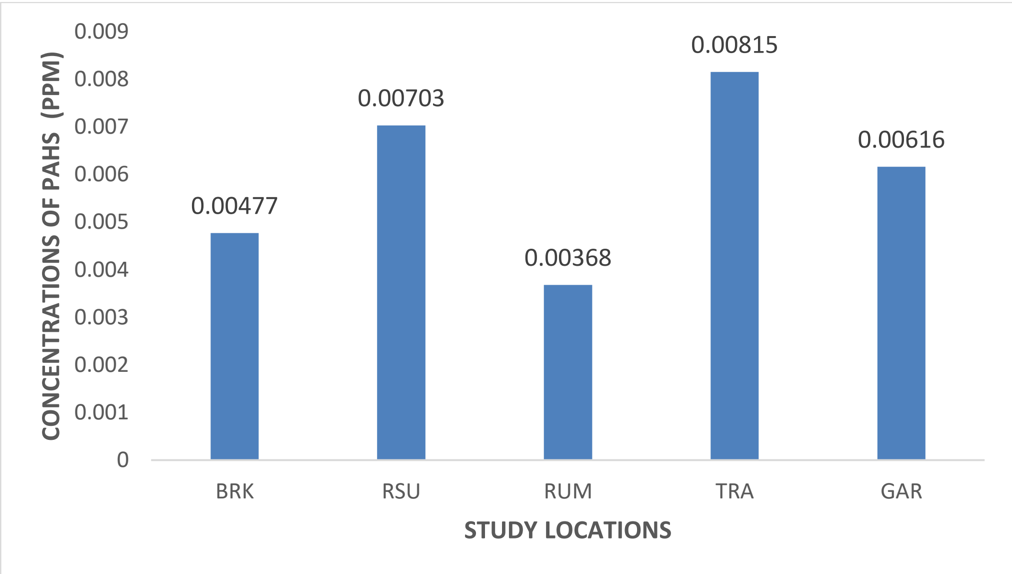

FIGURE 2: Dry Season Total PAHs in fruits of *Citrus sinensis* in Port Harcourt Metropolis

Location RSU recorded significantly higher concentrations of Pyrene (7.99 x10^{-4} ppm), Benzo (b) fluoranthene (1.58 x10^{-4} ppm), Benzo (k) fluoranthene (8.63 x10^{-4} ppm), Benzo (a) Pyrene (2.44 x10^{-4} ppm) and Dibenz (a,h) anthracene (3.01 x10^{-3} ppm) (Table 1). This report is in consonance with the report by Trinya and Ideriah (2015) that observed high concentrations of NO_2 and SO_2 exceeding permissible limits at Rivers State University of Science and Technology Farm and Road E. The high concentration of PAH observed at this location can be attributed to industrial activities from the adjacent Nigerian Agip Oil company and automobile activities from the busy Mile 3 Park which is in close proximity with the Rivers State University.

Acenaphthylene was detected only at location GAR which is a high traffic location. Location GAR also had significantly higher concentrations of Naphthalene (4.98 x10^{-5}) Flouranthene (5.62 x10^{-5} ppm), Dibenz (a, h) anthracene (3.05 x10^{-3} ppm) and Indeno (1,2,3-cd) pyrene (1.14 x10^{-3} ppm). This result agrees with the report by WHO (2003) which states that automobiles are a major source of PAHs in the environment. Naphthalene, Acenaphthene and Chrysene were not detected in location BRK a low traffic location. Location BRK also recorded significantly lower concentrations of Pyrene, Dibenz (a, h) anthracene and Benz (a) Pyrene (Table 1). This result can be attributed to the low vehicular and industrial activities within and around the Borikiri axis of Port Harcourt Metropolis and is in agreement with the report by Emerhi *et al*, (2012).

TABLE 1
PAHS (PPM) DETECTED IN FRUITS OF *CITRUS SINENSIS* GROWN AROUND PORT HARCOURT METROPOLIS

PAHs	**Location/Season**									
	Dry Season					**Wet season**				
	BRK	**RSU**	**TRA**	**RUM**	**GAR**	**BRK**	**RSU**	**TRA**	**RUM**	**GAR**
Naphthalene	BDL	BDL	BDL	$3.65x10^{-5\ (b)}$	$4.98x10^{-5\ (a)}$	BDL	BDL	BDL	BDL	BDL
Acenaphthylene	BDL	BDL	$8.28\ x10^{-3(a)}$	BDL	BDL	BDL	$2.96\ x\ 10^{-3(a)}$	BDL	BDL	**BDL**
Fluorene	$2.641x10^{-5(a)}$	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Anthracene	BDL	$6.05\ x10^{-5\ (a)}$	BDL	BDL	BDL	BDL	$5.33\ x\ 10^{-6\ (b)}$	BDL	BDL	$1.72\ x\ 10^{-5\ (a)}$
Flouranthene	$2.98\ x10^{-5(b)}$	BDL	$5.41\ x10^{-5(a)}$	$1.05\ x10^{-5(c)}$	$5.62\ x10^{-5\ (a)}$	BDL	$7.08\ x\ 10^{-6\ (c)}$	$1.46\ x\ 10^{-4\ (a)}$	BDL	$4.54\ x\ 10^{-5\ (b)}$
Benzo (g, h, i) perylene	$2.03x10^{-3\ (a)}$	BDL	$3.37x10^{-4\ (c)}$	BDL	$1.12x10^{-3(b)}$	$1.17\ x\ 10^{-4(c)}$	$9.8\ x\ 10^{-5(c)}$	$8.34\ x\ 10^{-4(a)}$	BDL	$4.33\ x\ 10^{-4(b)}$
Pyrene	$5.39X10^{-5\ (d)}$	$7.99X10^{-4\ (a)}$	$2.60X10^{-4\ (d)}$	$2.73X10^{-4\ (b)}$	BDL	$6.1\ x\ 10^{-5(c)}$	$4.55\ x\ 10^{-6(d)}$	$7.74\ x\ 10^{-5\ (b)}$	BDL	$9.79\ x\ 10^{-5(a)}$
Benz (a) anthracene	$2.15X10^{-5\ (b)}$	$2.76X10^{-4\ (a)}$	BDL	$1.52X10^{-5\ (c)}$	BDL	$1.64\ x\ 10^{-5\ (b)}$	$5.77\ x\ 10^{-6\ (d)}$	$1.05\ x\ 10^{-4(a)}$	BDL	$1.52\ x\ 10^{-5(c)}$
Chrysene	BDL	$1.59X10^{-3\ (b)}$	$5.68X10^{-3\ (a)}$	$1.21X10^{-3\ (c)}$	BDL	$2.82\ x\ 10^{\ (b)}$	$3.23\ x\ 10^{-5\ (d)}$	$4.78\ x10^{-4(a)}$	BDL	$2.71\ x\ 10^{-4(c)}$
Benzo (b) fluoranthene	$8.99X10^{-5\ (c)}$	$1.58X10^{-4\ (a)}$	BDL	$7.69X10^{-5\ (d)}$	$1.21X10^{-4\ (b)}$	$3.66\ x\ 10^{-5\ (b)}$	$1.83\ x\ 10^{-6\ (d)}$	$7.91\ x\ 10^{-5\ (a)}$	BDL	$2.47\ x\ 10^{-5\ (c)}$
Benzo (k) fluoranthene	$1.26X10^{-3\ (a)}$	$8.63X10^{-4\ (a)}$	BDL	$3.79X10^{-4\ (b)}$	$5.18X10^{-4\ (c)}$	$7.89\ x\ 10^{-5\ (b)}$	$1.33\ x\ 10^{-5\ (d)}$	$3.29\ x\ 10^{-4\ (a)}$	BDL	$4.37\ x\ 10^{-5\ (c)}$
Benzo (a) Pyrene	$0.37X10^{-4\ (d)}$	$2.44X10^{-4\ (a)}$	$1.60X10^{-4\ (c)}$	$1.46X10^{-4\ (b)}$	$0.84X10^{-4\ (c)}$	$1.78\ x\ 10^{-4\ (a)}$	$1.8\ x\ 10^{-4(a)}$	$1.48\ x\ 10^{-5\ (b)}$	BDL	$1.64\ x\ 10^{-5\ (b)}$
Dibenz (a, h) anthracene	$2.52X10^{-4\ (e)}$	$3.01X10^{-3\ (a)}$	$8.81X10^{-4\ (d)}$	$1.40X10^{-3\ (c)}$	$3.05X10^{-3\ (a)}$	$1.06\ x\ 10^{-4(c)}$	$1.48\ x\ 10^{-5(d)}$	$4.64\ x\ 10^{-4(a)}$	BDL	$2.83\ x\ 10^{-4(b)}$
Indeno (1,2,3-cd) pyrene	$7.77X10^{-4\ (c)}$	BDL	$8.01X10^{-4\ (b)}$	BDL	$1.14X10^{-3\ (a)}$	$5.34\ x\ 10^{-4(c)}$	$1.6\ x\ 10^{-4(d)}$	$1.71\ x\ 10^{-3(a)}$	BDL	$7.01\ x\ 10^{-4(b)}$

Within columns means with different superscripts are significantly different at $p \leq 0.005$ using the DMRT

TABLE 2
PAHS (PPM) DETECTED IN FRUITS OF *CITRUS SINENSIS* GROWN AROUND PORT HARCOURT METROPOLIS AGAINST PERMISSIBLE LIMITS

PAH	LOCATIONS										
	Dry Season					Wet Season					
	BRK	RSU	RUM	TRA	GAR	BRK	RSU	RUM	TRA	GAR	USEPA 2013
Naphthalene	BDL	BDL	3.65 x10^{-5}	BDL	4.98x10^{-5}	BDL	BDL	BDL	BDL	BDL	4.0 x10^{-2}
Acenaphthylene	BDL	BDL	BDL	8.28 x 10^{-3}	BDL	BDL	2.96 x 10^{-3}	BDL	BDL	BDL	2.0 x10^{-1}
Fluorene	2.641 x 10^{-5}	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2.0 x10^{-1}
Anthracene	BDL	6.05 x10^{-5}	BDL	BDL	BDL	BDL	5.33 x 10^{-6}	BDL	BDL	1.72 x 10^{-5}	2.0 x10^{-1}
Flouranthene	2.98 x 10^{-5}	BDL	1.05 x10^{-5}	5.41 x10^{-5}	5,62 x10^{-5}	BDL	7.08 x 10^{-6}	BDL	1.46 x 10^{-4}	4.54 x 10^{-5}	2.0 x10^{-1}
Benzo (g, h, i) perylene	2.03 x 10^{-3}	BDL	BDL	3.37 x10^{-4}	1.12 x 10^{-3}	1.17 x 10^{-4}	9.8 x 10^{-5}	BDL	8.34 x 10^{-4}	4.33 x 10^{-4}	3.0 x10^{-1}
Pyrene	5.39 x10^{-5}	7.99 x10^{-4}	2.73 x10^{-4}	2.60 x10^{-4}	BDL	6.1 x 10^{-5}	4.55 x 10^{-6}	BDL	7.74 x 10^{-5}	9.79 x 10^{-5}	2.0 x10^{-1}
Benz (a) anthracene	2.15 x 10^{-5}	**2.76 x10^{-4}**	1.52 x10^{-5}	BDL	BDL	1.64 x 10^{-5}	5.77 x 10^{-6}	BDL	1.52 x 10^{-5}	**1.05 x 10^{-4}**	**1.0 x10^{-4}**
Chrysene	BDL	1.59 x10^{-3}	1.21 x10^{-3}	5.68 x10^{-3}	BDL	2.82 x 10^{-4}	3.23 x 10^{-5}	BDL	4. 78 x 10^{-4}	2.71 x 10^{-4}	2.0 x10^{-1}
Benzo (b) fluoranthene	8.99 x 10^{-5}	1.58 x10^{-4}	7.69 x10^{-5}	BDL	1.21 x10^{-4}	3.66 x 10^{-5}	1.83 x 10^{-6}	BDL	7.91 x 10^{-5}	2.47 x 10^{-5}	2.0 x10^{-1}
Benzo (k) fluoranthene	1.26 x10^{-3}	8.63 x10^{-4}	3.79 x10^{-4}	BDL	5.18 x 10^{-4}	7.89 x 10^{-5}	1.33 x 10^{-5}	BDL	3.29 x 10^{-4}	4.37 x 10^{-5}	2.0 x10^{-1}
Benzo (a) Pyrene	0.37 x 10^{-4}	**2.44 x10^{-4}**	1.46 x10^{-4}	1.60 x10^{-4}	0.84 x 10^{-4}	1.78 x 10^{-4}	1.8 x 10^{-4}	BDL	1.48 x 10^{-5}	1.64 x 10^{-5}	**2.0 x10^{-4}**
Dibenz (a, h) anthracene	2.52 x10^{-4}	3.01 x10^{-3}	1.40 x10^{-3}	8.81 x10^{-4}	3.05 x10^{-3}	1.06 x 10^{-4}	1.48 x 10^{-5}	BDL	4.64 x 10^{-4}	2.83 x 10^{-4}	
Indeno (1,2,3-cd) pyrene	7.77 x 10^{-4}	BDL	BDL	8.01 x10^{-4}	1.14 x 10^{-3}	5.34 x 10^{-4}	1.6 x 10^{-4}	BDL	1.71 x 10^{-3}	7.01 x 10^{-4}	4.0 x10^{-1}

BDL: Below Detectable Limit

3.2 Wet Season PAHs in Fruits of *Citrus sinensis* Grown around Port Harcourt Metropolis:

Twelve individual PAHs were detected in fruits of *Citrus sinensis* around Port Harcourt metropolis in the wet season. Naphthalene and Fluorene were not detected in the wet season months. PAHs detected are Acenaphthene, Anthracene, Flouranthene, Pyrene, Benz (a) anthracene, Chrysene, Benzo (b) fluoranthene, Benzo (k) fluoranthene, Benzo (a) Pyrene, Dibenz (a,h) anthracene, Indeno (1,2,3-cd) pyrene and Benzo (g, h, i) perylene (Table 1).

Total PAHs concentration detected in fruits of *Citrus sinensis* within Port Harcourt metropolis in the wet season were significantly different at $P \leq 0.05$ using Duncan Multiple Range Test (DMRT). Concentration detected in Trans-Amadi (4.0×10^{-3} ppm) were significantly higher than the concentrations detected in the other locations (Fig 3). This can be attributed to the high industrial and vehicular activities in the Trans-Amadi axis of Port Harcourt and agrees with the report by WHO (2003) which states that automobiles are a major source of PAHs in the environment. RUM had the lowest with concentration below detectable limit (BDL) as shown in Figure 3. This report can be attributed to the low vehicular activities in the region due to the construction of the RUM flyover at the time of the study. This report is in consonance with Eduardo (2006) which reported that the burning of hydrocarbons in the engines of vehicles give rise to air pollutants. Result in table 1 shows that Acenaphthene was detected only in location RSU (2.96×10^{-3} ppm). Anthracene was detected in two locations (Garrison: 1.72×10^{-5} and RSU:5.33×10^{-6} ppm). Trans Amadi recorded the highest concentrations of Flouranthene (1.46×10^{-4} ppm), Benz (a) anthracene (1.05×10^{-5} ppm), Chrysene (4.78×10^{-4} ppm), Benzo (b) fluoranthene (7.91×10^{-5} ppm), Benzo (k) fluoranthene (3.29×10^{-4} ppm), Dibenz (a,h) anthracene (4.64×10^{-4} ppm), Indeno (1,2,3-cd) pyrene (1.71×10^{-3} ppm) and Benzo (g, h, i) perylene (8.34×10^{-4} ppm).

Individual PAHs at location RUM were all below detectable limits in the wet season. Location RSU recorded significantly higher concentrations of Benzo (a) Pyrene in both wet and dry seasons. Individual PAHs observed in fruits of *Citrus sinensis* within Port Harcourt metropolis in the wet season were all within the permissible limits recommended by the United States Environmental Protection Agency as opposed to what was detected in the dry season where the concentrations of Benz (a) anthracene and Benzo (a) Pyrene in location RSU (2.76×10^{-4} ppm and 2.44×10^{-4} ppm respectively) were above recommended limits (Table 2). Concentrations of Benzo (a) anthracene however, were within the border line with a concentration of 1.04×10^{-4} ppm. The low concentrations of PAHs observed in the wet season months can be attributed to the fact that pollutant emissions and concentrations are higher during the dry seasons owing to meteorological factors such as high temperature. Efel *et al* (2005) reported that during the wet season, a combination of heavy rainfall and in some cases, high wind speed off the oceans, significantly improve pollutant concentrations in the environment.

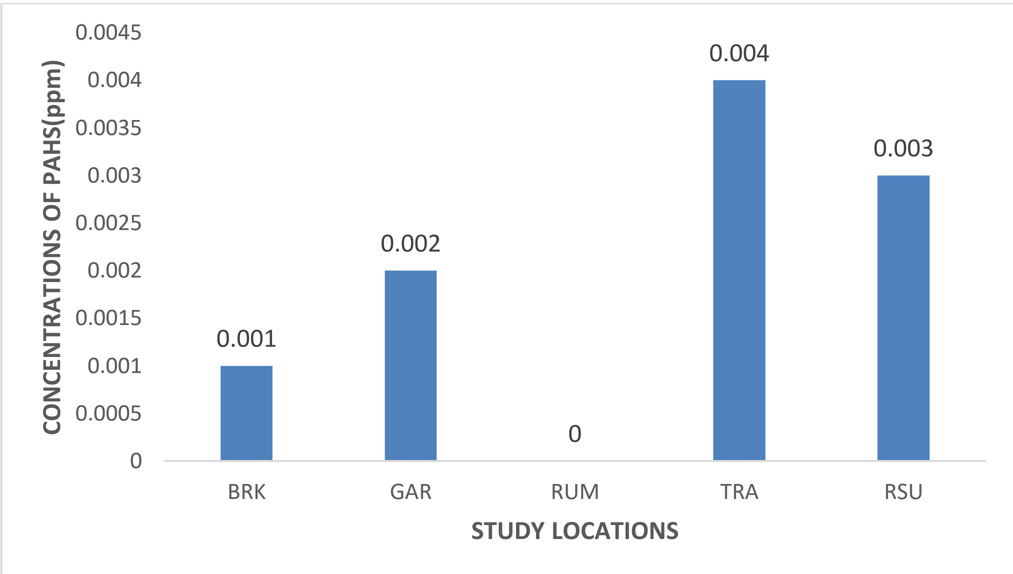

FIGURE 3: Wet Season Total PAHs in Fruits of *Citrus sinensis* within Port Harcourt Metropolis

IV. CONCLUSION

The findings from this study have provided evidence of the presence and levels of PAHs in fruits of *Citrus sinensis* grown around Port Harcourt metropolis in the dry and wet seasons. In the dry season, carcinogenic and mutagenic polycyclic aromatic hydrocarbons such as Benz (a) anthracene and Benz (a) pyrene were observed to have concentrations higher than the standard limit in *Citrus sinensis* fruits grown within the Rivers State University. In the wet season Benzo (a) anthracene was observed to be within the standard limit at the Garrison location. The distribution of PAHs in fruits within Port Harcourt Metropolis should be monitored regularly due to the toxicological effect and widespread presence in the environment. The biological impact in terms of total PAHs intake into the body via polluted fruits should be monitored. Further studies and sensitization by relevant authorities should be done to identify the sources and health implications of exposure to PAH.

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An Assessment of the Role and Effectiveness of the Environmental Protection Agency in Ensuring Food Safety and Production in Osun State, Southwestern Nigeria

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***Abstract*—** *The relevance of food to human health and survival cannot be over-emphasized. It enhances the development and growth of the people when it is correctly handled, while inappropriate supervision of food could bring ailment and sicknesses. The study examined the level of performance of the Environmental Protection Agency, food safety practices by food handlers, and potential factors affecting the effectiveness of the Environmental Protection Agency strategy in food production in Osun State, Southwestern, Nigeria. The descriptive and quantitative approaches used to conduct this study have Environmental agencies in Osun State as respondents with the application of SPSS and R software packages. A T-test was carried out to find out the difference in the responses of the respondents. The finding revealed that the food supply to the consumers is edible and of good quality is part of the agency's role (83.1%). This study established that environmental protection agencies are charged with the responsibility to secure a quality environment suitable for good health and well-being, protect people in the society against food that is injurious to health and enter the food business premises at a reasonable time and regularly. The results showed that the level of performance of environmental agencies in educating the populace that everybody stands an equal chance of being affected by food poisoning is very high (98.8%). The finding showed that agencies always advocate that the health status of workers should be evaluated before employment (96.4%). The results indicated that swollen cans may contain the microorganism, clostridium botulism, which causes botulism (92.4%). The results revealed that food handlers did not use gloves during the distribution of unpacked food (72.3%). The result also indicated that food handlers were not checking the shelf life of food at the time of delivery (67.5%). The results showed that the major factor affecting the effectiveness of the Environmental Protection Agencies (96.4 %). The findings showed that there was a significant statistical difference ($p<0.05$) in the responses of respondents. The study concluded that environmental protection agencies have important roles to play in food processing, but some factor affect their effectiveness.*

***Keywords*— Environmental protect agency, health, Food processing, Food safety. Legislation.**

I. INTRODUCTION

The Environmental Protection Agency (EPA) is a federal agency created in 1970 to protect human health and the environment by researching and regulating the production, processing, distribution and use of chemicals and other pollutants. The Environmental Protection Agency (EPA) is charged with creating and enforcing regulations that protect people and the planet from the harmful impacts of pollutants, not just in our environment but also in food and animal feed and water [1,2]. So, with that said, an environmental agency or environmental protection agency is a multi-signature organization or commission tasked with protecting the environment, resource management, and preservation and established within or outside of government. They also said that these agencies must preserve the environment from the misuse of its resources due to human degradation of the environment by climate change. For humans to exploit the earth's environmental resources sustainably for generations to come, we need proper environmental management [3].

Haris et al. [4] continued that food processing is the conversion of raw materials into finished products. This involves establishing connections through time, but also physical space: food is one of the most basic human necessities. proved that food is key to life and the basis for all that we do. Food is needed mainly to preserve life [5,6], and food must be wholesome and palatable, devoid of untoward compounds, including lethal chemicals, toxins, and infectious microorganisms [7]. Inefficient or inappropriate food processing technologies, inadequate post-harvest handling practices and unavailability or lack of storage facilities, packing houses and inadequate market infrastructures are some of the factors that can be attributed to the high level of post-harvest food losses in West Africa (8) Food must be handled, prepared and stored in such a way as to avoid causing foodborne diseases such as cholera and gastroenteritis [9]. Environmental factors play a role in street food safety. These are knowledge and awareness about food safety measures, low food hygiene practices and lower socioeconomic conditions for food vendors, poor attitude of food vendors toward food safety, socio-cultural beliefs, and trust [10,11].

Foodborne and waterborne diarrheal diseases cause an estimated 2.1 million deaths annually, mainly among children in developing countries [12,13]. The Nigerian government has a National Policy on Food Hygiene and Safety, which was implemented as part of the National Health Policy in 2010. To achieve high food hygiene and safety practices to promote health, control food-borne diseases, and minimize and eventually eliminate the risk of diseases associated with poor food hygiene and safety is the overall goal of the National Policy on Food Hygiene and Safety [14,15].

Responsible agencies are required to do the following: protect the public from harm caused by the consumption of unwholesome food, ensure that all food establishments are properly inspected and registered, and conduct public health surveillance of food handlers and food processing equipment. educate the public on proper hygiene and safety procedures [16,17]. However, the challenge of food quality and safety in Nigeria, whether for domestic consumption or exportation, requires serious attention. However, Agbola [18] discovered that 45% of his respondents in his study of food insecurity among farming households in Osun State, Nigeria, were food insecure using the Food Security Index Similarly, Banjoko *et al*. [19] Assessment of the Information Needs of Street Food Vendors in Ilorin East Local Government Area of Kwara State. However, these two study did not consider the roles of environmental protection agencies, hence this study evaluates the roles of the environmental protection agency, assess the performance of the environmental protection agency strategy in food production, examine food safety practices by a food handler, and investigate problems associated with the effectiveness of environmental protection agency in food production in Osun State Nigeria.

II. MATERIALS AND METHODS

2.1 Description of study area:

Research Area Osun State lies between latitudes 6º551 and 8º101 North and longitudes 3º551 and 5º051 East of South Western Nigeria [20]. It covers a landmass of about 7997.5484 square kilometres and an estimated 2001 population of 2,854,832 (NPC, 1997). Osun State was created in 1991 out of Old Oyo State. It is located in the rainforest ecological zone of the country. They are neighbouring Oyo, Ekiti, Kwara and Ondo states. The state has luxuriant vegetation, extensive rainforest (generally in the southern part of the state) and sub-savanna forests [21].

2.2 Research design:

Huysamen [22] further states that the design can be explained as the plan or logic followed during the process of collecting data to answer the research hypothesis or question in the most economical way. This study was conducted with a descriptive and quantitative approach to research. This study is described as such because descriptive studies provide information about characteristics and a picture of the current roles of environmental protection agencies in the Osun State.

2.3 Population and sample size:

The target population refers to the entire set of individuals or elements who meet the sampling criteria [23]. In this study, an accessible population is the portion of the target population to which the researcher has reasonable access [23]. In this study, the accessible population included workers of the Osun State Ministry of Environment and Workers of Osun State Waste Management Agency, Osogbo. The sample size of this study is eighty-three (83).

2.4 Validity:

The instrument was subjected to expert judgment engaging professionals from the Institute of Ecology and Environmental Studies, faculties of health sciences and Education to assess the relevance to the subject matter, its scope, and coverage.

2.5 Reliability:

Reliability was established by ensuring internal consistency through the items which constituted the questionnaire and the reliability statistical test revealed that Cronbach's Alpha coefficient is 0.792, a measure that the instrument used in this study is reliable. Table 1 depicts Cronbach's Alpha coefficient.

TABLE 1
CRONBACH'S ALPHA COEFFICIENT

Reliability Statistics	
Cronbach's Alpha	**No. of Items**
0.792	36

2.6 Data collection method:

This study makes use of primary data obtained via the direct distribution of a questionnaire by the researcher to the respondents in two environmental protection agencies. The researcher also provided them with a little description of what the questionnaire was all about to ensure valid, reliable and accurate data and also to provide a greater response rate. 150 questionnaires were prepared, 86 were administered, and 83 were returned and properly completed.

2.7 Data analysis:

According to Alem [24], data analysis provides possible solutions to an unspecified phenomenon, requiring the researcher to interpret the data that has been gathered it and to present the results in a very manageable and concise manner which enables the researcher to make an overall statement on a population based on a sample using an objective method free of feelings and ambiguities. The data collected for the study were coded and entered into location windows V.20 of SPSS for analysis and a T-test was conducted in the R software package to determine response differentials among the respondents. P values <0.05 were considered statistically significant.

III. RESULT AND DISCUSSION

3.1 Identify the roles of the environmental protection agency in food production:

The responsibility of the government is to ensure that the established standards, legislation and enforcement programmes are kept by the food industry to ensure food quality and safety [16, 25]. However, Table 2 below identified the role of environmental agencies in food production in which 67.6% of respondents subscribed to the fact that environmental agencies spread from the federal to state level while 2.4% rejected it. This implies them aware of their roles at the state level. While 83.1 % of the respondents accepted that assuring that the food supply to the consumers is edible and of good quality is part of the agency's role, the remaining 17.9% of the respondents rejected it. The table below also showed that 94% of the respondents subscribed to the fact that taking appropriate steps to ensure food safety and quality of domestic consumption and exportation remains one of the roles of the environmental agency whereas 6.0 % unsubscribed to it and this is in agreement with findings of Ezirigwe [26] and Wu et al., [27]. With responses from respondents, 98% of respectively, this study established that environmental agencies are charged with the responsibility to secure a quality environment suitable for good health and well-being, protect people in the society against food that is injurious to health and enter the food business premises at a reasonable time and regularly and this result is in agreement with Kuppusamy et al.[28], who gave a report on the Integrating AI in food contaminant analysis: Enhancing quality and environmental protection. Almost all the respondents (92.7%) followed the study against the statement "Your agency restrains the sale of food that is unhygienically prepared, adulterated, spoilt, contaminated, and improperly labelled, an implication that restrains the sale of food that is unhygienically prepared, adulterated, spoilt, contaminated, and improperly labelled is not part of responsibility of the environmental agency and this result is inconsistent with findings of Ojinnaka [16] who maintained that restriction on the sale of food that has been improperly prepared, adulterated, contaminated, spoilt, or labelled is part of environmental agency responsibility. However, the result is also consistent with Adebowale and Kassim [29], who worked on food safety and health: a survey of rural and urban household consumer practices, knowledge of food safety and food-related illnesses in Ogun state. The result of findings from the table below indicated that all the respondents agreed that environmental protection agencies educate the populace that infectious agents cause food poison which implied that it is part of their roles. All these imply that the agencies complied with government policy on food hygiene and safety in discharging their duties Nyor [30]. There was a significant statistical difference ($p<0.05$) in the responses of respondents in identifying the roles of the Environmental Protection Agency in Food Production in accordance with this study's findings Table 3

TABLE 2
IDENTIFY ROLES OF THE ENVIRONMENTAL PROTECTION AGENCY IN FOOD PRODUCTION

S/N	Questions	Yes	No
		(%)	
1	Agency spreads from Federal to State level	98	2.4
2	Assures that the food supply to the consumers is edible and of good quality	83	18
3	Taking appropriate steps to ensure food safety and quality of domestic consumption and exportation	94	6
4	Charging with the responsibility to secure a quality environment suitable for good health and well being	99	1.2
5	Protects people in society against food that injurious to health	99	1.2
6	Restrains the sale of food which are unhygienically prepared, adulterated, spoilt, contaminated, and improperly labeled	7.3	93
7	Enters the food business premises at a reasonable time and regularly	99	1.2
8	Educates the populace that infectious agents cause food poison	100	0

TABLE 3
INDICATES SUMMARY OF TWO SAMPLE t-TESTS OF IDENTIFY ROLES OF ENVIRONMENTAL PROTECTION AGENCY IN FOOD PRODUCTION

	Yes	No
Mean value	84.8	15.325
t -value	4.3695	
p-value	0.0006415	
df	14	

3.2 Assessment of the level of performance of the environmental protection agency:

Table 4 below shows the level of performance of the Environmental Protection Agency, which is very important because Food processing is a very sensitive area that affects the entire economy, and the quality of food consumed by the Nigerian population determines their health, and a healthy nation is a wealthy nation. In examining whether the agencies educating the populace that everybody stands an equal chance of being affected by food poisoning from the respondents, this study indicated that the Environmental Protection Agency performed very well (98.8%). This implies a high level of performance by the agencies. The majority of the respondents (84.3%) affirmed the fact that the environmental agencies create awareness that reheating cooked foods can contribute to food contamination to food contamination while the remaining 15% disagreed and this is consistent with the findings of Amaami *et al* [31] who maintained that there is a high awareness of food safety among food vendors. The results are consistent with the findings of Khalil et al. [32], who worked on the Preemptive and proactive strategies for food control and biosecurity. The result above is also in line with Onyeaka et al. [33]. The result of the findings of this study also demonstrated that all the respondents indicated that the agency always brings it to the notice of the populace that typhoid fever is transmitted by food, an implication which showed the total performance of the agency in that specific area [34]. Out of a total number of respondents, a total number of 96.4% agreed, whereas only 3.6% disagreed with the fact that the agency always advocates that the health status of workers should be evaluated before employment. This also indicated a high level of performance of the agency. In assessing the level of performance of the Environmental Protection Agency in the area of making it open to the populace that salmonella is among the food-borne pathogens, the majority of respondents (95.2%) complied with it. This finding is in agreement with the findings of He et al. [35]. The study survey showed that the majority of respondents (70%) believed that the environmental agency always brings it to the notice of the populace that HAV is among the food-borne pathogens, which implied that the high level of performance of the agency in that regard is consistent with Kearney [36]. In relating the performance of the agency with a question that says once make it known that swollen cans may contain the microorganism, clostridium botulism, which causes botulism, 92.4% of respondents affirmed it while 7.6% of respondents rejected it. All findings as regards the level of performance of the Environmental Protection Agency in this study are not consistent with the findings of Amaami *et al* [31] who stated that the effectiveness of regulatory bodies was generally fair (50%) and this may be as a result of the different methodology adopted. It was also established from this study that there was a significant statistical difference (p<0.05) in response of respondents to the level of performance of the Environmental Protection Agency in Food Production

TABLE 4
ASSESSMENT OF THE LEVEL OF PERFORMANCE OF THE ENVIRONMENTAL PROTECTION AGENCY

S/N	Questions	Percentage level of response (%)		(n=83)	
		Agree	Strongly agree	Disagree	Strongly disagree
9	Educates the populace that Everybody stands an equal chance of being affected by food poison	67.5	31.3	1.2	0
10	Creates enough awareness that reheating cooked foods can contribute to food contamination	53	31.3	13.3	2.4
11	Always bring to the public's attention that typhoid fever is transmitted by food.	63.9	36.1	0	0
12	Always advocate that the health status of workers should be evaluated before employment	63.9	32.5	3.6	0
13	Making it open to the populace that Salmonella is among foodborne pathogen	68.7	26.5	3.6	1.2
14	Always bring it to the notice of the Populace that HAV is among the food-borne pathogen	70.7	24.4	4.9	0
15	Once make it know that swollen cans may contain the microorganism, clostridium, Botulinum which causes botulism	71.1	21.7	6	1.2

Source: Field survey, 2023

TABLE 4
INDICATES SUMMARY OF TWO SAMPLE T-TESTS OF THE POSSIBLE LEVEL OF PERFORMANCE OF ENVIRONMENTAL PROTECTION AGENCY AND FOOD SAFETY PRACTICES BY FOOD HANDLERS

	Agree +strongly agree	Disagree +strongly disagree
Mean value	94.657143	5.342857
t-value	32.362	
p-value	0	
df	12,	

3.3 Food safety practice by the food handler:

Food laws and regulations attempt to protect the health of consumers. These laws have been kept in place to guide food providers to ensure proper food handling and to ensure the serving of wholesome food to the general public [37, 38]. As regards educating and training food manufacturers and handlers on safe food handling procedures, Environmental health officers and the Environmental Protection Agency are all supportive. They also help in inspecting facilities where food is being cooked for compliance with current safety standards [38, 11]. From Table 6, it was established from the above results that the majority of the respondents (72.3%) confirmed that food handlers did not use gloves during the distribution of unpacked food, while only 27.7% confirmed they used gloves. This implies that food quality control which is deliberate efforts to check the controllable factors that either positively or negatively influence the finished products during food processing is not put into consideration by the food handlers and this finding is not consistent with Food Standards [39] which states that food handlers must have the skills and knowledge that they need to handle food safely as they carry out their work. The Study is also not in agreement with Murwira et al.. [40], who reported on the Assessment of food handlers' compliance with personal hygiene practices in fast food outlets in Thohoyandou, South Africa. In relating food safety practices by food handlers in Table 6 with the question which says that food handlers cover their hair when distributing unwrapped food, 38.6% of the respondents agreed, but a large volume of respondents (61.4%) disagreed. This could be the result of the negligence of the environmental protection agency, and this implies that food safety is not considered and foods are generally prepared and sold under unhygienic conditions. The results from the above also indicated that food handlers were not checking the shelf life of food at the time of delivery, and this was confirmed with the majority of respondents' responses (67.5%). This finding was in line with Rane [41] and Al Mamun [42]. The findings from this study also showed that food handlers properly cleaned the food storage area before storing new ones (51.8%). This implies that food handlers obey the principal role of food packaging, which is to protect food products from outside influences and distribution damage, maintain food safety and minimize environmental impact [43]. It has been established from this study that there was a significant statistical difference ($p<0.05$) in the response of respondents to food safety practices by food handlers.

TABLE 6
FOOD SAFETY PRACTICE BY FOOD HANDLER

S/N	Questions	Percentage level of the response (%)	
		TRUE	FALSE
16	The producers/sellers of food normally use gloves during the distribution of unpackaged food	27.4	72.3
17	Covering the hair when distributing unwrapped food	38.6	61.4
18	Eating or drinking at the workplace	19.3	80.7
19	Always check the shelf life of food at the time of delivery	32.5	67.5
20	They properly clean the food storage area before storing new ones	51.8	48.2

Source: Field survey, 2023

TABLE 7
INDICATES SUMMARY OF TWO SAMPLE t-TESTS OF FOOD SAFETY PRACTICE BY FOOD HANDLER

	TRUE	FALSE
Mean value	33.92	66.02
t-value	-4.1512	
p-value	0.003204	
df	8	

3.4 Possible factors that could affect the effectiveness of the environmental protect agency:

Table 8 below shows possible factors that could be responsible for the ineffectiveness of the Environmental Protection Agency and from this table, it indicated that out of the total number of respondents, 69.9%, 20.5%, 4.8%, and 4.8% agreed, strongly agreed, disagreed and strongly disagreed respectively to the fact that agency facing a challenge from the higher office could be a possible factor. The majority of the respondents (57.8% and 28.4%) disagreed and strongly agreed, respectively, while the remaining 14.5% and 19.3% agreed and strongly disagreed, respectively, to the fact that there are enough funds and allocations to carry out assigned responsibilities from the federal. This implies that the federal government is not funding the environmental agencies appropriately, and it is consistent with the findings of Akuu et al. [44] and Maji et al. [45], who maintained that regulatory bodies failed to perform their duties due to a lack of logistics and resources. The survey from the table below revealed that most of the respondents (49.4% and 39.8%) disagreed and strongly disagreed, whereas the remaining 0% and 10.8% strongly agreed and agreed, respectively, that Salaries and other welfare packages are paid as at when due. Table 8 showed that 73.5% and 22.9% of the total respondents agreed and strongly agreed, respectively, to the question of facing any challenge whenever they charged those who violated the rules of the agency, and the remaining 3.6% and 0% disagreed and strongly disagreed, respectively. Undue political interference from the federal government remains part of the possible factors affecting the effectiveness of environmental protection agencies [46] and Liu et al. [47]. This is also evident from this study as the majority (94.0%) of respondents agreed that there is undue political interference from the federal government in achieving the aims of the agency.

A very small number of the respondents, 3.6% and 1.2% disagreed, and strongly disagreed, respectively, that corruption is one of the factors influencing environmental protection agencies while most of the respondents (69.9% and 25.1%), agreed and strongly agreed. The result is in agreement with Ganda [48] who worked on the the influence of corruption on environmental sustainability in developing economies. The majority of the respondents from Table 8 (50.6% and 27.7%) agreed and disagreed with whether religion plays a role in carrying out the activities of the agency whereas the remaining respondents 16.9% and 4.8% strongly agreed and strongly disagreed respectively, an implication that religion is not left out as regards the factors affecting the functionality of the environmental protection agency in Osun State. Indication from Table 8 revealed that very few numbers of the respondents (7.2% and 14.5%) strongly agreed and strongly disagreed respectively that environmental protection agencies at times do not consult the local people and traditional leaders for preferred activities before embarking on it while the majority of the respondents (54.2% and 24.1%) agreed and disagreed. The survey showed that the same number of respondents (1.2%,) disagreed and strongly disagreed with the fact that the low educational level of many food business operators could be one of the factors responsible for the ineffectiveness of environmental protection agencies whereas the larger number of the respondents (66.3% and 31.3%) agreed and strongly agreed respectively and this is in line with findings of Subratty, Beecharry, and Chan sun (2004).

TABLE 8
POSSIBLE FACTORS THAT COULD AFFECT THE EFFECTIVENESS OF THE ENVIRONMENTAL PROTECTION AGENCY

S.No.	Questions	Percentage level of the respondents (%)			
		Agree	Strongly agree	Disagree	Strongly disagree
21	Facing any challenge from the higher office	69.9	20.5	4.8	4.8
22	There are enough funds and allocations to carry out the assigned responsibilities from the federal level	14.5	28.4	57.8	19.3
23	Salaries and other welfare packages are paid as of when due.	10.8	0	49.4	39.8
24	Facing any challenge whenever they charged those who violated the rules of the agency	73.5	22.9	3.6	0
25	There is undue political interference from state and federal government in achieving the aims of the agency	69.9	24.1	3.6	2.4
26	Corruption is one of the factors influencing environmental protection agency	69.9	25.3	3.6	1.2
27	Religion plays a role in carrying out the activities of the agency	50.6 1	16.9	27.7	4.8
28	Environmental protection agencies at times do not consult the local people and traditional leaders for preferred activities before embarking on it	54.2	7.2	24.1	14.5
29	The low educational level of many food business operators	66.3	31.3	1.2	1.2

Source: Survey field, 2023

TABLE 9
INDICATES SUMMARY OF TWO SAMPLE T-TESTS OF POSSIBLE FACTORS THAT COULD AFFECT THE EFFECTIVENESS OF THE ENVIRONMENTAL PROTECTION AGENCY

	Agree +strongly agree	Disagree +strongly disagree
Mean value	72.91111	27.06667
t-value	3.2121	
p-value	0.005	
df	16,	

3.5 Mean and mean ranking possible factors that affected the effectiveness of the environmental protection agency

Following the result from the mean ranking of the possible factors that could affect the effectiveness of the agency " religion plays role in carrying out the activities of the agency is the least factor while the unpaid salary and other is the most factor affecting the effectiveness of the agency Table 10

TABLE 10
MEAN AND MEAN RANKING POSSIBLE FACTORS THAT AFFECTED THE EFFECTIVENESS OF THE ENVIRONMENT PROTECTION AGENCY

S/N	Questions	(1) Mean	(2) Rank
30	There are enough funds and statutory allocations to carry out assigned responsibilities at the federal level	1.45	3
31	Your salaries and other welfare packages are paid as when due	2.82	2
32	Does your agency face any challenge whenever they charge those who violated the rules of the agency in court	3.18	1
33	There is undue political interference from the state and federal government in achieving the aims of the agency	0.53	8
34	Corruption is one of the factors influencing environmental protection agency	0.68	5
35	Religion plays a vital role in caring out the activities of the environmental protection agency strategy	0.61	7
36	The agency at times did not consult the local people and the traditional leaders for the preferred activities before embarking on it	0.1	9
37	The low educational level of many food business operators	1.17	4
38	Are you facing any challenges from the higher offices of the agency	0.58	6

Source: Field survey, 2023

IV. CONCLUSION

In conclusion, this study is timely because it is inspired by the reality that food processing is a very sensitive area that affects the entire economy and the quality of food consumed by the Nigerian population determines their health. A healthy nation is a wealthy nation which means enforcement and supervisory powers of the regulatory agencies should be strengthened to cover food for local consumption since the majority of Osun State people are low-income earners and depend on food prepared or manufactured locally. The findings from this study indicated an assessment of the roles of environmental protection agencies in food processing. It was indicated from this study that, food safety practices by food handlers were ineffective and inadequate. The findings from this study also revealed that some factors hindered the effectiveness of environmental protection agencies. This study concluded that environmental protection agencies have important roles to play in food processing but some factor affect their effectiveness. It also concluded from this study that food is generally prepared and solid under unhygienic conditions.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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Bioherbicidal Potential of Some Plant Extracts in Weed Control in West-Cameroon

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Abstract— *The use of herbicides poses problems of multifaceted environmental pollution, toxicity and depletion of microflora and microfauna in the soil. Farmers and environmentalists are powerless in the face of this problem. However, certain plant extracts are known for their allelopathic properties through their allelochemicals, which is primarily demonstrated by their effectiveness on weeds. It is in this context that the present study was conducted, with the aim of evaluating the bioherbicidal efficacy of extracts of Cupressus lusitanica, Bambusa vulgaris and Ricinus communis on Bidens pilosa, a weed frequently found in cultivated plants and which causes enormous crop losses. To achieve this objective, 75 seeds of these weeds were sterilised using 0.5% sodium hypochlorite for 2 minutes. Subsequently, 15 Petri dishes were prepared with plant extract, then filter paper was moistened with 2 ml of distilled water and placed at the bottom of each Petri dish. Seventy-five (75) previously sterilised weed seeds were placed in each of these Petri dishes at a rate of 5 per dish. Each seed was sprayed with 1 ml of each extract at concentrations of 7.5, 15 and 30 mg/ml. The Petri dishes containing distilled water and those sprayed with the herbicide at the manufacturer's recommended dose were used as negative and positive controls, respectively. All of the dishes were placed in a growth chamber at 23 ± 1°C in the dark. From the second day of incubation, the seeds were carefully observed for any signs of germination, and when this was visible, it was counted and noted, and the lengths of the stems, the number of leaves and their surface areas were measured. The highest concentrations of the extracts that had shown some efficacy in vitro were brought back to the field for bioherbicide testing under pre-emergence conditions.*

The results showed that all three plant extracts significantly inhibited the germination of Bidens pilosa seeds compared to the negative control. However, the percentage of inhibition of weed seed germination was significant at the highest concentrations. Thus, concentrations of 30 mg/ml of the three plant extracts were the most effective, with no germination of Bidens spilosa seeds, i.e. a rate of 0%. On the other hand, the highest germination rates were observed with concentrations of 7.5 and 15 mg/ml. These rates varied between 26.67 and 80% and were similar to those of the negative controls according to Duncan's 5% test. Of all three concentrations of the different plant extracts tested in the field, only those of Cupressus lusitanica were the most effective in significantly destroying the leaves of Bidens pilosa.

These results suggest the possibility of using extracts from this plant at a concentration of 30 mg/ml to control this weed, however further studies are needed to complete the information associated with this.

Keywords— Bioherbicide, plant extracts, Cupressus lusitanica, Bambusa vulgaris, Ricinus communis, weed.

I. INTRODUCTION

Weeds are one of the main causes of crop losses. These adventitious plants can compete with cultivated plants for nutrients or serve as shelters for pathogens that can attack these plants and cause considerable economic damage. In response to this damage, several weed control methods are available, including mechanical and thermal methods. However, these methods have proven ineffective, and farmers are still forced to resort to chemical herbicides. Furthermore, the application of these chemical herbicides on weeds poses risks to consumers and the environment, in addition to the development of resistant weeds (Uddin *et al*., 2014; Sofiene, 2020). Furthermore, some herbicides are limited on the market and others, such as glyphosate, are gradually being withdrawn from the market. However, public demand for alternative herbicides that are biological in origin (bioherbicides) and more environmentally friendly is growing. Medicinal plants are known for their bioherbicidal properties and low or no toxicity. Researchers have been exploring this avenue for some time with a view to formulating bioherbicides that are safe for consumers and environmentally friendly. In fact, the work of Sofiene Ben Kaab (2020) has shown that *Rosmarinus officinalis* essential oil and *Cynara cardunculus* extract have high bioherbicidal activity compared to extracts of *Trifolium incarnatum (T. incarnatum), Sylibum marianum (S. marianum)* and *Phalaris minor*, which showed low activity on weeds.

Similarly, Claudia *et al*. (2022) on the bioherbicidal activity of *Campomanesia lineatifolia* seed extract on the weed *Sonchus oleraceus* L. showed a 100% incidence of chlorosis and necrosis symptoms with foliar application of this plant extract, but these applications did not result in complete plant death. However, all of these previous studies are limited in terms of both the plant extracts tested and the number and diversity of weeds on which they were tested. It is in this context that the present work was carried out with the aim of evaluating the bioherbicidal of plant extracts on *Bidens pilosa* under pre- and post-germination conditions.

II. MATERIALS AND METHODS

2.1 Preparation of plant extracts:

The young leaves of the harvested plants were dried in the shade for two weeks, then finely ground in a mill, and the resulting powder was stored in jars away from light until use. Extraction was carried out at the University of Dschang's Research Unit for Microbiology and Antimicrobial Substances (URMSA), using ethanol as the extraction solvent for each plant. The extracts were obtained by macerating 250 g of powder from each plant for 48 hours in 500 ml of solvent. The mixture was first filtered using coffee filter paper and then Whatman No. 1 filter paper. The residues from the various ethanol extracts were placed in an evaporative rotator flask for partial evaporation of the solvent (ethanol) before being completely dried in an oven at a temperature of 40°C. The yield of the extract (Rdt%) was calculated using the following formula (Njimah, 2022)

$$Rdt\ (\%) = M_1/Mo\ x100 \quad (1)$$

Where Mo is the mass of the processed plant material, M_1 is the mass of the extract, and Rdt is the extraction yield.

2.2 Evaluation of the bioherbicidal activity of extracts from *Cupressus lusitanica, Bambusa vulgaris* and *Ricinus communis* on pre-emergence weeds

The *Bidens pilosa* seeds were sterilised using 0.5% sodium hypochlorite for 2 minutes. Subsequently, 15 Petri dishes were prepared with plant extract, then filter paper was moistened with 2 ml of distilled water and placed at the bottom of each Petri dish. Seventy-five (75) previously sterilised weed seeds were placed in each Petri dish at a rate of 5 per dish. Each seed was sprayed with 1 ml of each extract at concentrations of 7.5, 15 and 30 mg/ml. The Petri dishes containing distilled water and those sprayed with the herbicide at the manufacturer's recommended dose were used as negative and positive controls, respectively. All of the dishes were placed in a growth chamber at 23 ± 1°C in the dark. From the second day of incubation, the seeds were carefully observed for any signs of germination, which were counted and noted when visible. The length of the stem and the number of leaves were then measured until the seventh day using a graduated ruler (mm). The percentage of inhibition was determined using the following formula:

$$Percentage\ inhibition\ (\%) = n/\ N\ x\ 100 \quad (2)$$

Where n represents the number of seeds that germinated, and N represents the total number of seeds sown.

2.3 Evaluation of the bioherbicidal activity of plant extracts on weeds under post-emergence conditions:

Twenty-four (24) *Bidens pilosa* seeds were sown separately in bags containing soil that had been disinfected in a Chamberlain autoclave at 121°C for 15 minutes. The seeds were watered daily from the second day onwards and after germination and plant development until 2 to 3 leaves appeared. Nine of these adventitious plants were sprayed with each plant extract at concentrations of 7.5, 15 and 30 mg/ml. Three others were also watered with 1 ml of water, and those treated with herbicides served as negative and positive controls, respectively. The experiment was carried out in triplicate. Data on the development of physiological parameters such as necrosis were recorded from the second day of treatment until the seventh day. The data collected were used to calculate the percentage of efficacy according to the following formula:

$$(\%)\ \text{Efficacy} = N / T \times 100 \qquad (3)$$

Where **N** represents the number of necrotic or wilted leaves, and **T** represents the total number of leaves.

III. RESULTS AND DISCUSSION

3.1 Characteristics and yield of plant extracts:

The table below shows the characteristics and yield of the plant extracts used for the bioherbicide test. This yield varied depending on the extract, the harvest period and the harvest location. The table shows that *Bambusa vulgaris* extracts had the highest extraction yield (11.11). On the other hand, the lowest yields were obtained with *Cupressus lusitanica*. In terms of appearance and colour, *Cupressus lusitanica* was creamy with a brown colour, while Bambusa vulgaris was thick and black. *Ricinis communis* had a black-brown colour and a thick appearance. The variation observed in yields could be attributed, on the one hand, to intrinsic factors of the plant and, on the other hand, to the plant species, the period of the plant's vegetative cycle and/or the plant family. Indeed, Smallfield (2001) reported that environmental conditions, harvest period and age of plant material can influence extraction yields. Djeugap *et al*. (2011) showed that certain plant families offer high yields compared to others that give low yields: *Annonaceae, Myrtaceae, Asteraceae* and *Zingiberaceae* generally offer very high yields, unlike Poaceae (*Cymbopogon citratus*), which has very low yields.

TABLE 1
CHARACTERISTICS AND YIELD OF PLANT EXTRACTS USED

Plants used	Extraction yield	Physical appearance	Color
Bambusa vulgaris	11,11	Thick	black
Ricinus communis	7,2	thick	black brown
Cupresus lustanica	7,45	creamy	brown

3.2 Effect of extract concentrations on germination percentage:

Table 2 presents the results of the effect of ethanol extracts of Cupressus lusitanica, *Rinusus communis* and *Bambusa vulgaris* on the germination of *Bidens pilosa* seeds on the 7th day. In general, all three plant extracts significantly inhibited the germination of *Bidens pilosa* seeds compared to the negative control. The work of Sofiene Bens Kaab (2020) on the study of the herbicidal potential of plant extracts from Tunisian xero-halophytic species and the determination of their modes of action revealed that phenolic extracts from *Cynara cardunculus* and essential oil from *Rosmarinus officinalis* have bioherbicidal properties. The percentages of inhibition of weed seed germination were significant at the highest concentrations. Thus, concentrations of 3 mg/ml of extracts from three plants were the most effective, showing the lowest germination rate of *Bidens pilosa* seeds, i.e. 0%. These results are similar to those of Melakhessou *et al*. (2023), who also noted in their experiment that the inhibition of Bromus rubens and durum wheat growth increases as the concentration of the extract applied increases. On the other hand, the highest germination rates were observed with concentrations of 7.5 and 15 mg/ml. These rates varied between 26.67 and 80% and were similar to those of the negative controls according to Duncan's test at 5%.

However, weed seeds treated with Supermachette herbicide (positive controls) at the concentration recommended by the manufacturer showed high germination rates (73.33%) on the seventh day of the experiment (Figure 1). Nevertheless, although these seeds treated with herbicides germinated, they did not grow but instead withered and dried out (Table 3). This trend suggests that the herbicide used does not act on germination but rather on the plant itself. This could also be explained by the fact that the various seeds germinated before the various active ingredients in the herbicide penetrated the weed seeds, especially since their walls did not facilitate the rapid entry of these active ingredients. These observations are consistent with those of Macharia & Peffley (1995), who found in their work that winter onion extract (*Allium fistulosum*) does not affect the germination of *Kochia scoparia* seeds, although it significantly reduces the biomass of these seedlings.

TABLE 2
EFFECTS OF DIFFERENT PLANT EXTRACTS ON THE GERMINATION RATE OF WEED SEEDS

Concentrations (mg/ml)	Plant Extracts		
	Cupressus lusitanica	*Ricinus communis*	*Bambusa vulgaris*
7,5	26,67±11,55^{bA}	53,33±11,55^{bAB}	60,00±20,00^{bB}
15	53,33±11,55^{cAB}	80,00±20,00^{cBC}	13,33±11,54^{aA}
30	00,00±00,00^{aA}	00,00±00,00^{aA}	00,00±00,00^{aA}
T+	73,33±11,55^{dBC}	73,33±11,55^{bcBC}	73,33±11,55^{bcBC}
T-	93,33±11,55^{eC}	93,33±11,55^{eC}	93,33±11,55^{eC}

a, b, c and d: comparison of the percentages of inhibition of weed seed germination by plant extracts. Averages marked with the same letter in the same row are not significantly different according to Duncan's test at 5%. A, B, C and D: comparison of the percentages of inhibition of weed seed germination by plant extracts. Averages marked with the same letter in the same column are not significantly different according to Duncan's test at 5%. T+: Positive controls (Supermachette herbicide at a concentration of 5.33 mg/ml); T-: Negative controls (1 ml of distilled water)

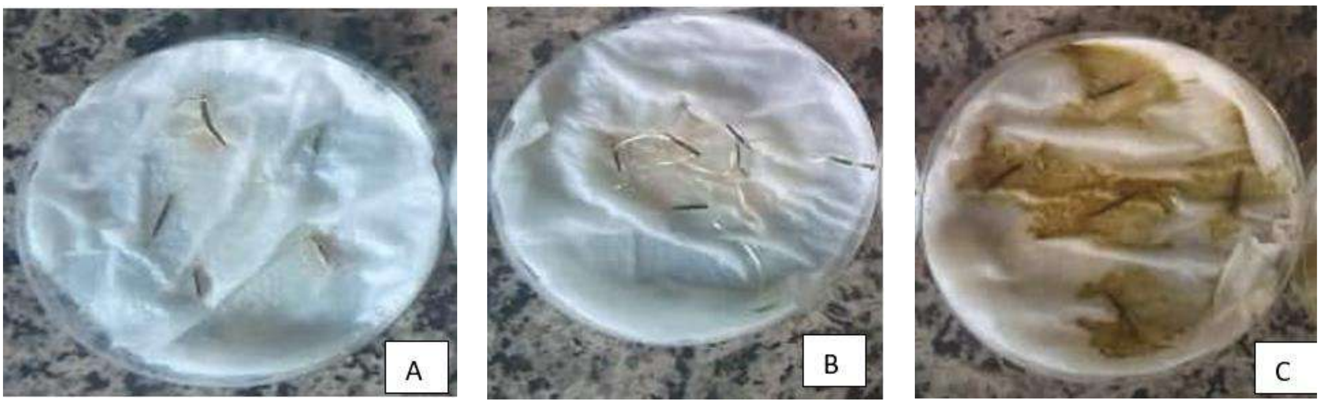

FIGURE 1: Seeds of the weed that underwent different treatments; (A): Seeds treated with Supermachette herbicide (positive control); (B): Seeds that underwent no treatment (negative control) and (C): Seeds treated with *Cupressus lusitanica* extracts at a concentration of 30mg/ml

3.3 Effect of different concentrations of extracts on the length of *Bidens pilosa* stems:

On the seventh day of the experiment, we also evaluated the effect of different concentrations of plant extracts on the length of the weed stems, and the results are presented in the table below. We observed a significant difference in the length of the stems of *Bidens pilosa* seedlings treated with different concentrations of ethanol extracts compared to those treated with herbicide and water. The seeds treated with the highest concentration of the three plant extracts had the shortest stems, similar to those of the positive controls. This part of the weed appears to be one of the most sensitive to the various plant extracts. These results corroborate those of previous studies, which also showed that bioherbicidal activity increases with the concentration of the plant extracts used (Lamia *et al*., 2017 & Melakhessou *et al*., 2023).

TABLE 3
EFFECT OF DIFFERENT CONCENTRATIONS OF EXTRACTS ON THE LENGTH OF *BIDENS PILOSA* STEMS

Concentrations (mg/ml)	Plant extracts		
	Cupressus lusitanica	*Ricinus communis*	*Bambusa vulgaris*
7,5	02,77±00,49^{b}	03,97±00,45^{c}	02,63±01,29^{b}
15	02,58±00,73^{b}	02,80±01,00^{bc}	00,17±00,29^{a}
30	00,00±00,00^{a}	00,62±00,60^{a}	00,00±00,00^{a}
T+	00,62±00,60^{a}	00,62±00,60^{a}	00,62±00,60^{a}
T-	03,17±00,40^{b}	03,17±00,40^{b}	03,17±00,40^{b}

a, b, c and d: comparison of the effect of plant extracts on the length of Bidens pilosa stems. Means marked with the same letter in the same row are not significantly different according to Duncan's test at 5%. T+: Positive controls (Supermachette herbicide at a concentration of 5.33 mg/ml); T-: Negative controls (1 ml of distilled water)

3.4 Effect of different concentrations of extracts on the number of leaves of *Bidens pilosa:*

Table 4 shows the effect of different concentrations of extracts on the number of *Bidens pilosa* leaves. This table shows that all extracts significantly reduced leaf growth. However, all three extracts at the highest concentration (30 mg/ml) completely prevented the development of weed leaves according to Duncan's 5% test compared to the positive controls. These results are similar to those of Fatima *et al*. (2011), who demonstrated that at high concentrations, *Peganum harmala* extracts had a suppressive effect on weeds.

TABLE 4
EFFECT OF DIFFERENT CONCENTRATIONS OF EXTRACTS ON THE NUMBER OF LEAVES OF *BIDENS PILOSA*

Concentrations (mg/ml)	Plant Extracts		
	Cupressus lusitanica	*Ricinus communis*	*Bambusa vulgaris*
7,5	01,17±00,29^{b}	01,89±00,20^{b}	01,83±00,29^{b}
15	01,61±00,35^{bc}	01,83±00,29^{b}	01,33±01,15^{b}
30	00,44±00,76^{a}	00,00±00,00^{a}	00,00±00,00^{a}
T+	02,00±00,00^{c}	02,00±00,00^{c}	02,00±00,00^{c}
T-	02,00±00,00^{c}	02,00±00,00^{c}	02,00±00,00^{c}

a, b and c: comparison of leaf growth of weed seeds treated with plant extracts. Averages marked with the same letter in the same row are not significantly different according to Duncan's test at 5%. T+: Positive controls (Supermachette herbicide at a concentration of 5.33 mg/ml); T-: Negative controls (1 ml of distilled water).

3.5 Effectiveness of the most effective plant extract concentrations in pre-germination conditions on weeds in post-germination conditions:

The table below (Table 5) shows the effect of the highest concentration of the three plant extracts on the leaves and the areas of damage caused by each extract. This table shows that all three extracts damaged the weed leaves to the same extent as the positive control. With regard to the lesion area, no lesions were observed on the leaves treated with *Bambusa vulgaris* extracts. However, the other two extracts significantly reduced the leaf surface area, with lesion areas between 0.23 and 0.24 cm2 greater than those of the negative controls but less than those of the positive controls according to Duncan's 5% test (Figure 2). Bens *et al.* (2020) also showed that *Cynara cardunculus* extracts and *Rosmarinus officinalis* essential oil had bioherbicidal properties under post-germination conditions. Similarly, the work of Claudia *et al*. (2022) on the bioherbicidal activity of *Campomanesia lineatifolia* seed extract on the weed *Sonchus oleraceus* L. showed a 100% incidence of chlorosis and necrosis symptoms with foliar application of this plant extract, but these applications did not result in plant death. The bioherbicidal activity observed in *Cupressus lusitanica* could be attributed to its high content of secondary metabolites. (Njimah *et al*., 2024) had already reported in their work that extracts from this plant are rich in secondary metabolites such as tannins, phenols, flavonoids, saponins, triterpenoids, anthocyanins and anthraquinones.

TABLE 5
EFFECTIVENESS OF THE 30 MG/ML CONCENTRATION OF THE THREE PLANT EXTRACTS ON THE LEAVES AND LESION AREAS (cm^2) INDUCED BY EACH EXTRACT ON THE FIFTH DAY OF TREATMENT

Treatments	Efficacy of extracts (%)	Lesion area (cm^2)
Cupressus lusitanica	02,78±01,07^{bc}	00,24±00,05^{b}
Ricinus communis	02,67±01,15^{bc}	00,23±00,03^{b}
Bambusa vulgaris	01,17±00,29^{ab}	00,00±00,00^{a}
T+	03,33±01,33^{c}	100,00±00,00^{c}
T-	00,00±00,00^{a}	00,00±00,00^{a}

a, b and c: comparison of the effectiveness of the extracts on the number of leaves and on the surface area of lesions induced on the leaves of weeds after spraying with plant extracts. Means marked with the same letter in the same row are not significantly different according to Duncan's test at 5%. T+: Positive controls (Supermachette herbicide at a concentration of 5.33 mg/ml); T-: Negative controls (1 ml of distilled water)

FIGURE 2: Lesion areas caused by *Cupressus lusitanica* extracts on *Bidens pilosa* leaves at a concentration of 30 mg/ml, (A): Positive and negative controls, (B): Plants treated with *Cupressus lusitanica* extracts and (C): Lesion area induced by *Cupressus lusitanica* extracts on leaves on the fifth day of treatment

IV. CONCLUSION

Having completed this work, the objective of which was to evaluate the bioherbicidal efficacy of extracts of *Cupressus lusitanica*, *Bambusa vulgaris* and *Ricinus communis* on *Bidens pilosa*, a weed frequently found in cultivated plants and causing enormous crop losses, it appears that all three plant extracts significantly inhibited the germination of *Bidens pilosa* seeds compared to the negative control. However, the percentages of inhibition of weed seed germination were significant at the highest concentrations. Thus, concentrations of 30 mg/ml of the three plant extracts were the most effective, with no germination of *Bidens pilosa* seeds, i.e. a rate of 0%. On the other hand, the highest germination rates were observed with concentrations of 7.5 and 15 mg/ml. These rates varied between 26.67 and 80% and were similar to those of the negative controls according to Duncan's 5% test. Of all three concentrations of the different plant extracts tested in the field, only those from *Cupressus lusitanica* were the most effective in significantly destroying *Bidens pilosa* leaves compared to those from *Bambusa vulgaris*, *Ricinus communis* and the negative controls. These results suggest the possibility of using extracts from this plant at the recommended concentration to control this weed, but further studies are needed to supplement the data obtained in this research.

CONFLICT OF INTEREST STATEMENT

Authors declare that they have no conflict of interest.

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Quality Assessments for Irrigation Waters used in Agricultural Fields of Konya - Meram Hatunsaray Neighborhood

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Abstract— *This study was conducted to assess the quality of water samples taken from irrigation wells used for irrigating agricultural fields of Hatunsaray neighborhood of Meram district, Konya province. Within the scope of the study, water samples were collected from the wells used for irrigation and soil samples were also collected from the agricultural fields irrigated with these wells at depths of 0-30, 30-60 and 60-90 cm. Irrigation water and soil samples were subjected to physical and chemical analyses. Majority of the soils in the region were loamy (L) and clay-loam (CL) in texture. Soil pH values varied between 7.94 - 9.10 and soil EC values between 242 - 857 µmhos/cm. Irrigation water EC values ranged from 198 to 772 µmhos/cm, while the pH values ranged from 6.91 to 8.38. Irrigation water samples were classified as* C_2S_1 *(moderately saline - low alkaline). To prevent salinity problems in agricultural lands, drainage systems should be established and maintenance and repairs of existing drainage channels should be carried out periodically. It is anticipated that the necessary cultural measures will prevent salinity problems in the coming years.*

Keywords— Irrigation, irrigation water quality, salinity, sodium content, soil salinity.

I. INTRODUCTION

Soil chemical properties play a great role in irrigated crops. Availability of different compounds in irrigation water is also largely dependent on soil properties. Salinity-induced soil loss of 10 million hectares annually serves as a dramatic example of soil-water quality interaction **[1].**

Water is the most important factor in agricultural production. Water and irrigation designate sustainable agricultural production especially in arid and semi-arid regions. Irrigation is the process of supplying the amount of water required by plants, which cannot be met by rainfall, to the plant root zone at proper time **[2].**

Water-air balance of the soil is disrupted when the balance between drainage and irrigation was not established. In such cases, soil air content decreases and yield losses are encountered then. Additionally, salinity and alkalinity issues arise. At the end, crop yields decrease or even cease entirely, depending on the levels of salinity and alkalinity. Soil must contain sufficient and appropriate levels of plant nutrients to achieve high-quality and abundant agricultural production. Excessive or insufficient levels of these nutrients negatively affect plant growth and development. Therefore, soil chemical and physical properties should be determined to solve problems encountered in agricultural production **[3].**

[4] indicated that besides irrigation method, timing and amount, irrigation water quality is also an important factor in modern irrigations. Unsuitable water is used in irrigation when sufficient and good-quality water is not available. Such a case increases soil salinity. Therefore, researchers took water samples from 10 irrigation ponds in June, July, August and September to evaluate the water quality in irrigation ponds used for irrigation in Hakkari Province. The following parameters were determined in the collected water samples: EC, pH, anions, and cations (Ca^{+2}, Mg^{+2}, K^{+}, Na^{+}, SO_4^{-2}, NO_3^{-2}, CO_3^{-2}, HCO_3^{-} and

Cl^-). Additionally, using the obtained data, Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC) and Sodium Percentage (% Na) values were also calculated. At the end of the study, it was determined that pH, EC, SAR, RSC and % Na values of the irrigation pond waters did not exceed the limit values, but the Mg^{+2} and K^+ values of the pond water in the Kanatlı area of Akçalı Village and the K^+ value of the pond water in the Şişer area of Kırıkdağ Village exceeded the limit values.

It was determined in a study on the effect of irrigation water of different qualities on alfalfa that growth slowed down in alfalfa irrigated with saline water and harvest yield and quality decreased. In contrast, when washing was performed and salt was removed from the environment, plant growth returned to normal levels. Accordingly, it was determined that for high alfalfa yields, irrigation water with salinity below 1.5 dSm^{-1} was appropriate **[5].**

[6] conducted a study in the Biga Plain of Çanakkale and examined the parameters of electrical conductivity (EC), pH, potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), carbonate (CO3), bicarbonate (HCO_3), Chloride (Cl), Sulfate (SO_4), Nitrate (NO_3) and Boron (B) in water samples collected from 20 wells. When classified according to the Water Pollution Control Regulation (SKKY) Classification System and considering the salinity parameter, 11 of the 20 wells were classified as second class, while the others were classified as first class.

[7] conducted a study in Isparta Plain and examined the quality of irrigation water samples taken from 21 groundwater wells. It was determined that water quality in some of the wells was classified as C_3S_1 (highly saline-low alkaline), while the water quality in other wells was classified as C_2S_1 (moderately saline-low alkaline).

[8] conducted a study to determine the impact of domestic and industrial wastes on the Nilüfer River. Wastewater samples were taken from the discharge points of five treatment plants discharging into the Nilüfer River and from the streams into which these plants discharge during four different periods between August 2013 and May 2014. It was determined that the wastewater quality parameters of the Nilüfer River and some of the wastewater treatment plants discharging into the Nilüfer River varied depending on the period. When the water parameters were examined before and after discharge from the Nilüfer River, it was determined that the wastewater discharged from the treatment plants had a negative impact on the Nilüfer River, particularly in terms of pH, EC, ammonium, phosphorus, sulfate, boron and chlorine values.

[9] conducted a study in the Sultanhisar district of Aydın Province and indicated that quality of water used for irrigation varied between C_2S_1 and C_3S_1 classes over time, canal water used affected fruit quality and boron content of these waters was higher than that of the control group.

[10] collected irrigation water samples from 12 greenhouse operations of Kırşehir province to determine the quality of irrigation water used in greenhouse operations. Soil samples were also collected from depths of 0–30 and 30–60 cm at the beginning and end of the production period. The pH values of irrigation water samples ranged from 5.47 to 8.61, while electrical conductivity (EC) values varied between 35 - 1720 dS m^{-1}. While calcium, magnesium and potassium concentrations of irrigation water did not pose any problems, 75% of the greenhouse operations had irrigation water with high sodium levels. Considering the crops grown, the soil reactions were found to be suitable for vegetable cultivation, but when EC values were examined, some greenhouse soils showed mild to moderate salinity. It was deemed important for greenhouse operations to regularly analyze irrigation water and monitor soil salinity levels for cultivation purposes.

[11] selected a total of 17 sampling sites along the Awash River and conducted sampling four times a year in different seasons to assess the water quality of the Awash River and its tributaries. Researchers explained the overall water quality and suitability for irrigation using numerous water quality parameters such as EC, pH, RSC, SAR, Na^+, K^+, Ca^{++}, Mg^{++}, CO_3^{2-}, HCO_3^- and Cl^-. It was indicated that all quality parameters in Lake Beseka exceeded the maximum permissible limits for irrigation, the physicochemical characteristics of the Awash River varied in different water quality parameters in different areas, only the pH and SAR of Beseka Lake and Meteka spring water exceeded the permitted limit and the EC values in Beseka, Mojo, Wonji, Melkasedi, Ambash, Werer, Meteka and Meteka springs showed medium-high salinity values, while the RSC was very high.

II. MATERIAL AND METHOD

Water samples were taken from 20 irrigation wells in some agricultural fields of Hatunsaray neighborhood of Meram district, Konya province in June, July, August, September and October. Soil samples were also taken from some agricultural fields irrigated by these wells.

Konya Province is located in the south of the Central Anatolia Region. Most of its land is high plains, while the southern and southwestern parts of Konya Province are in the Mediterranean Region. Geographically, Konya is located between 36°41' and 39°16' north latitudes and 31°14' and 34°26' east longitudes (Figure 1) **[12]**. Its total area is 38,257 km² (excluding lakes). It is the largest province of Turkiye. The average altitude is 1,016 m **[13].**

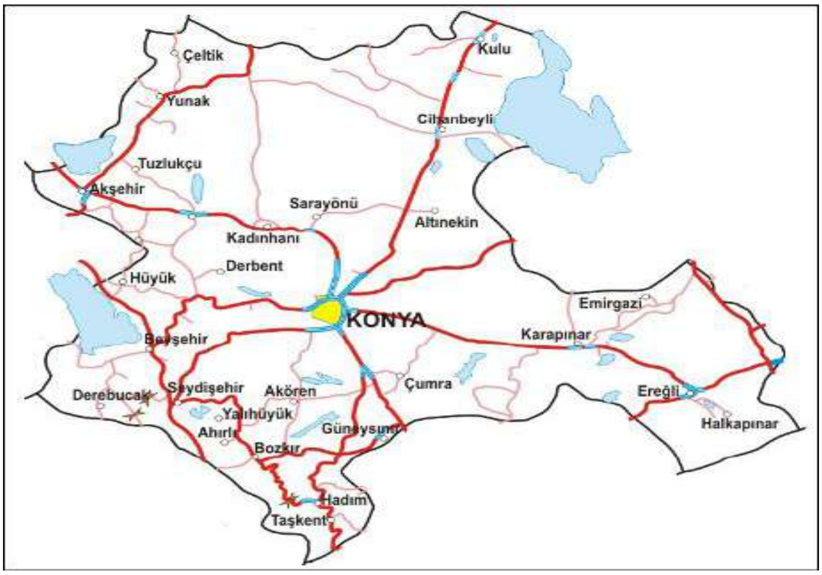


FIGURE 1: Map of Konya province (Anonymous, 2022)

Meram district, located 4 km from the center of Konya province, is located between 37°70' north latitudes and 32°30' east longitudes. Its altitude is 1,016 meters. The district is bordered with Beyşehir district to the west, Selçuklu district to the north, Karatay district to the east and Akören district to the south. The district has a total area of 1,680.2 km². The district is generally mountainous, with a flat area in the southeast. The region is mostly covered with steppe vegetation, with some forested areas.

The district has 168,021 ha of arable land. Meram district, which constitutes 4.2% of the arable lands of Konya province and 12.14% of the arable lands of the Lakes Basin, consists of 36.94% agricultural lands, 24.34% forest areas and 10.12% meadow-pasture areas. The forest areas in the district are larger than those in Konya Province **[14].**

At the high altitudes of Konya Province, where the terrestrial climate prevails, winters are cold and rainy, while summers are hot during the day and cool at night. The temperature difference between night and day is high and rainfall is quite low **[2].**

Convective rainfall occurs in spring and most precipitation falls during this season. The region's annual average precipitation is 329 mm. Due to the varying topography of Konya Province, average annual precipitation amounts also differ **[15].**

While the monthly average temperature values in the region range from -0.2°C to 23.5°C, a regular increase in temperature has been observed when long-term temperature changes are examined. Evaporation values reach their highest levels in the summer months. The evaporation value in July is 280 mm, with an annual total of 952 mm **[12].**

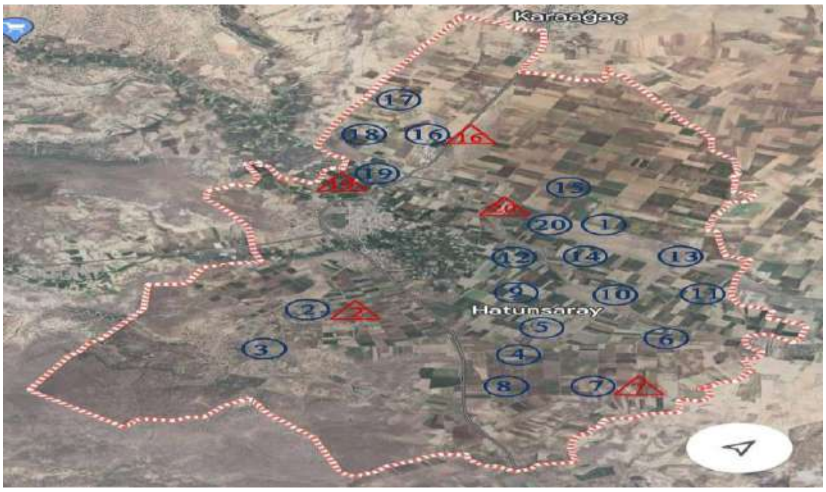
There is a total of 4,083,800 ha of agricultural land in Konya province. Including fallow land, the amount of arable land is 1,876,344 ha **[16]**. There are 620,638 decares of cultivated land in Meram. Of the land in the district, 57.60% is arable land, 26.61% is fallow land, 7% is vegetable land and 1.17% is fruit and vineyard land. The arable land in the district is less than the proportion of arable land in Konya Province, while the fallow land is more than the fallow land in the province.

The vegetable field ratio in Meram is significantly higher than that of Konya. The ornamental plant ratio is approximately 10 times higher **[14].**

The total agricultural land in the research area of Hatunsaray is 20,884 decares. Of these lands, 12,568 decares are used for irrigated agriculture, while 8,316 decares are used for dry farming **[13].**

In Hatunsaray, irrigation water is supplied from underground water wells and the Hatunsaray Reservoir. In the study, water samples were taken from 20 operational wells used for irrigation of agricultural lands. Water quality monitoring was conducted by taking water samples five times between June and October.

From three of the agricultural fields irrigated using the identified wells in the study area (fields numbered 16, 19, and 20), undisturbed and disturbed soil samples were collected at depths of 30 cm up to 90 cm in August and subjected to physical and chemical analyses in a laboratory setting. Soil samples were also collected from fields numbered 2 and 7 and subjected to chemical analysis along with the others. The locations where soil and water samples were collected are shown in Figure 2.



*** O irrigation water wells ** ∆ soil sampling sites**

FIGURE 2. Soil and water sampling sites

III. RESULTS AND DISCUSSION

In this study, samples were taken five times from irrigation wells used to irrigate agricultural lands, once a month in June, July, August, September, and October. The samples were numbered and their pH and EC values are shown in Table 1.

In June, pH values of irrigation water ranged from 6.91 to 7.98 and EC values ranged from 243 to 639 µmhos/cm; in July, pH values varied between 7.28 - 7.83 and EC values between 198 - 655 µmhos/cm; in August, pH values ranged from 6.91 to 7.87 and EC values ranged from 218 to 730 µmhos/cm; in September, pH values varied between 7.12 - 8.22 and EC values between 268 - 760 µmhos/cm; and in October, pH values varied between 7.23 - 8.38 and EC values between 201 - 772 µmhos/cm (Table 1).

The EC values of irrigation water samples taken from the region, categorized by month and sample number, are presented in Figures 3, 4, 5, 6 and 7.

The chemical analysis results of irrigation water samples taken from the research area in August are given in Table 2. The pH values of the waters were between 6.91 and 7.87, the EC values were between 218 and 730 µmhos/cm and the boron concentrations were between 0.289 and 0.417 ppm. It was observed that Ca was the dominant cation and HCO_3 was the dominant anion in the water. Sodium Adsorption Ratios (SAR) were found to be between 0.32 and 1.79 and % Na values were between 11.0 and 30.6. The highest amount of residual sodium carbonate (RSC) was determined to be 1.59 (if the RSC value exceeds 2.5, irrigation water is not suitable for agricultural irrigation and may cause adverse effects on the soil). The irrigation water class of the water samples taken from the research area in August is C_2S_1 according to the US Salinity Laboratory **[17]**

The salinity values of all irrigation samples taken from the wells were found to be below the safe upper limit (750 µmhos/cm) (except for 1-2 samples). It was also observed that the water obtained from these wells can easily be used in agricultural production.

The boron concentrations of the irrigation water samples are given in Table 2 and values are also presented in Figure 8. According to the August water analyses, it was determined that the boron concentrations of the irrigation water were below the safe limit (0.7 ppm) and did not pose any problems.

TABLE 1
THE pH AND EC VALUES OF IRRIGATION WATER SAMPLES

Sample No	June-2023		July-2023		August-2023		September-2023		October-2023	
	pH	EC x 10^6 µmhos/cm 25ºC	pH	EC x 10^6 µmhos/cm 25ºC	pH	EC x 10^6 µmhos/cm 25ºC	pH	EC x 10^6 µmhos/cm 25ºC	pH	EC x 10^6 µmhos/cm 25ºC
1	7,98	441	7,41	449	6,91	423	7,56	383	8,11	305
2	7,83	243	7,60	385	7,57	404	7,79	392	7,82	281
3	7,96	287	7,64	306	7,31	303	8,20	282	8,38	261
4	7,87	359	7,47	355	7,44	374	8,22	271	8,12	330
5	7,69	362	7,64	357	7,46	372	8,14	279	7,72	343
6	7,58	385	7,45	387	7,29	424	7,39	373	7,23	366
7	7,83	370	7,69	385	7,51	416	7,67	363	7,94	359
8	7,74	273	7,65	198	7,60	218	7,55	268	7,82	201
9	7,47	516	7,79	476	7,32	460	7,77	433	8,17	481
10	6,91	584	7,47	557	7,87	557	7,86	565	8,09	507
11	7,75	480	7,56	487	7,39	482	7,60	483	7,58	483
12	7,76	379	7,68	378	7,68	405	7,29	438	7,60	432
13	7,94	327	7,83	317	7,84	295	7,71	303	7,82	310
14	7,81	372	7,66	373	7,78	362	7,75	353	7,75	365
15	7,52	639	7,51	621	7,63	654	7,42	588	7,75	628
16	7,57	459	7,56	456	7,44	447	7,29	438	7,30	442
17	7,69	529	7,42	530	7,39	541	7,12	516	7,64	507
18	7,73	424	7,28	363	7,69	425	7,28	491	7,67	452
19	7,57	631	7,42	636	7,40	730	7,30	760	7,53	772
20	7,69	615	7,46	655	7,52	652	7,30	629	7,35	593

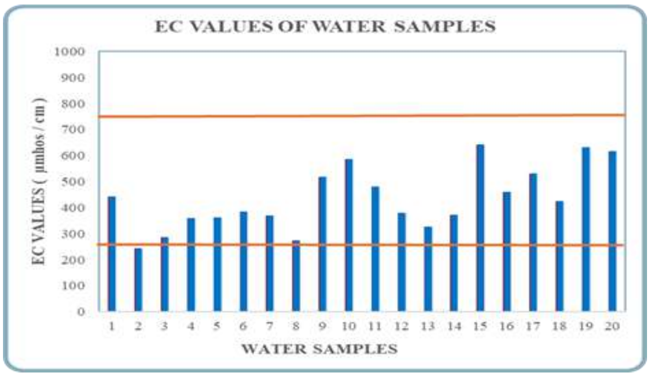


FIGURE 3. EC values of irrigation water in June

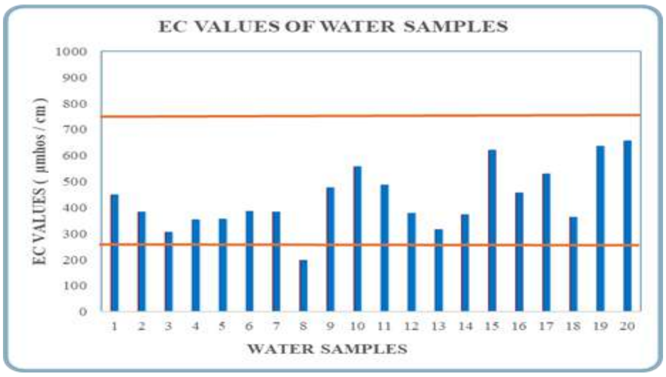


FIGURE 4. EC values of irrigation water in July

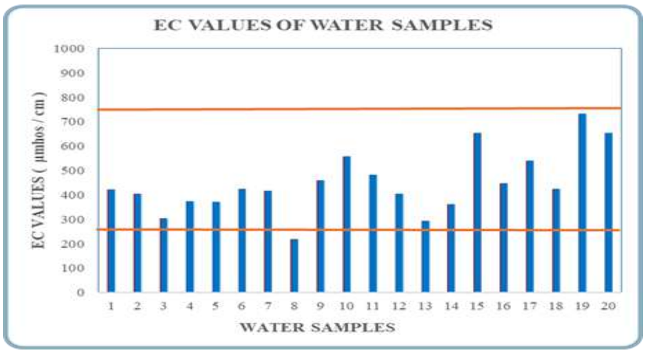


FIGURE 5 EC values of irrigation water in August

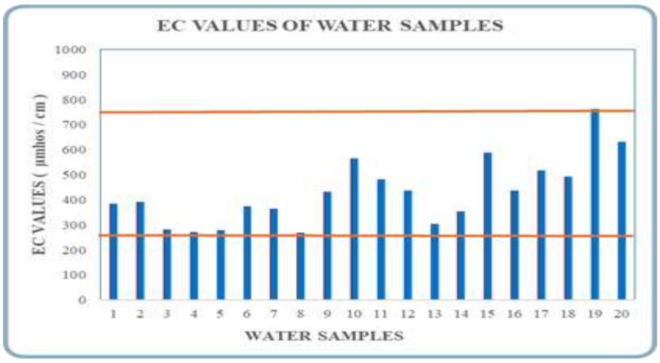


FIGURE 6. EC values of irrigation water in September

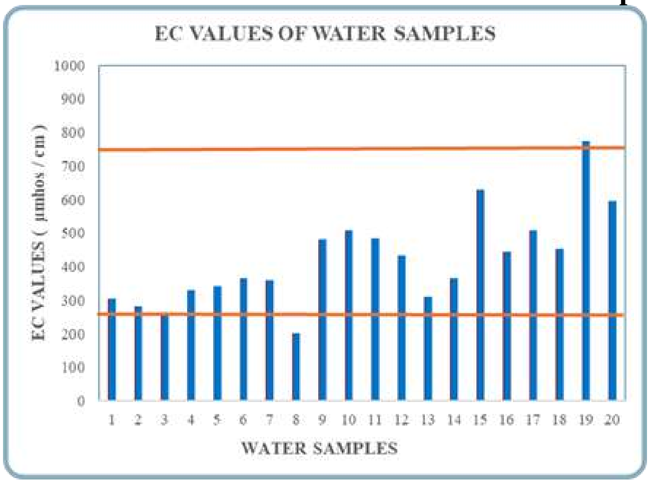


FIGURE 7. EC values of irrigation water in October

TABLE 2
CHEMICAL ANALYSIS RESULTS FOR WATER SAMPLES TAKEN IN AUGUST (2023)

No.	pH	ECx10^6 µmhos/cm 25ºC	Water-Soluble Cations (me/l) Na^+	K^+	Ca^{+2}	Mg^{+2}	Top.	Anions (me/l) CO_3^{-2}	HCO_3^-	Cl^-	SO_4^{-2}	Top.	RSC	SAR	%Na	Irrigation Water Class	Boron (ppm)
1	6,91	423	0,88	0,18	3,11	0,76	4,9	-	4,1	0,5	0,5	5,1	0,23	0,63	17,8	C_2S_1	0,413
2	7,57	404	0,84	0,18	3,07	0,6	4,7	-	4,9	0,5	0,3	5,7	1,23	0,62	17,9	C_2S_1	0,315
3	7,31	303	0,46	0,11	2,64	0,58	3,8	-	4,1	0,3	0,5	4,9	0,88	0,36	16,5	C_2S_1	0,294
4	7,44	374	0,71	0,11	2,22	0,49	4,5	-	4,2	0,3	0,7	5,2	1,49	0,61	20,1	C_2S_1	0,311
5	7,46	372	0,73	0,14	2,83	0,52	4,22	-	4,1	0,4	0,8	5,3	0,75	0,56	19,1	C_2S_1	0,291
6	7,29	424	1,18	0,25	2,96	0,54	4,93	-	4,7	0,5	0,6	5,8	1,2	0,89	27,3	C_2S_1	0,385
7	7,51	416	1,01	0,12	3,07	0,74	4,9	-	4,9	0,3	0,4	5,6	1,09	0,73	20,4	C_2S_1	0,319
8	760	218	0,36	0,08	2,03	0,43	2,9	-	2,1	0,2	0,8	3,1	-	0,32	16,5	C_2S_1	0,303
9	7,32	460	0,74	0,14	3,45	0,83	5,16	-	4,2	0,5	0,9	5,6	-	0,51	15,9	C_2S_1	0,327
10	7,87	557	0,77	0,16	3,67	0,99	5,6	-	4,8	0,8	0,6	6,2	0,14	0,50	13,8	C_2S_1	0,289
11	7,39	482	1,06	0,17	3,14	1,1	5,5	-	5,1	0,6	0,7	6,4	0,86	0,73	16,4	C_2S_1	0,306
12	7,68	405	0,72	0,17	2,81	0,99	4,7	-	4,5	0,5	0,8	5,8	0,7	0,52	12,7	C_2S_1	0,302
13	7,84	295	1,07	0,07	1,91	0,39	3,6	-	3,4	0,5	0,8	4,7	1,1	1,00	31,1	C_2S_1	0,351
14	7,78	362	0,97	0,07	2,54	0,58	4,2	-	3,9	0,7	0,6	5,2	0,78	0,78	23,3	C_2S_1	0,392
15	7,63	654	1,1	0,26	3,85	1,7	6,9	-	5,9	0,9	0,7	7,3	0,35	0,66	13,9	C_2S_1	0,34
16	7,44	447	1,07	0,06	2,96	0,82	4,9	-	4,6	0,8	0,5	5,9	0,82	0,78	22,7	C_2S_1	0,407
17	7,39	541	0,63	0,06	4,36	0,86	5,9	-	5,6	0,6	0,5	6,7	0,38	0,39	11,0	C_2S_1	0,363
18	7,69	425	0,9	0,16	2,63	0,89	4,6	-	4,8	0,5	0,6	5,9	1,28	0,68	17,7	C_2S_1	0,331
19	7,40	730	2,84	0,43	3,24	1,77	8,1	-	6,6	1,3	1,2	9,1	1,59	1,79	30,6	C_2S_1	0,417
20	7,52	652	1,29	0,26	3,66	1,56	6,8	-	5,9	1,0	0,7	7,6	0,68	0,80	17,0	C_2S_1	0,350

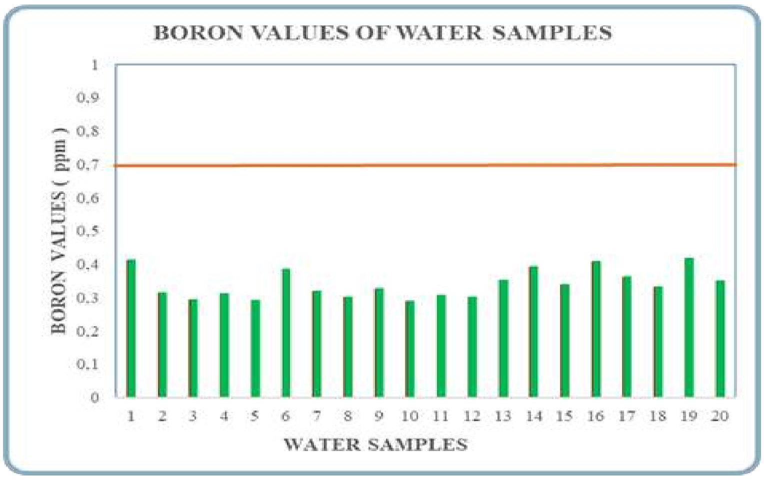


FIGURE 8: Boron concentrations of water samples in August

In the research area, disturbed and undisturbed soil samples were taken from depths of 0-30 cm, 30-60 cm and 60-90 cm in three areas irrigated with irrigation wells. The physical analysis of the soil samples was performed and results are presented in Table 3. Physical analysis results revealed that the saturation percentage values varied between 45 - 55%, the field capacity (FC) values between 29.15 - 32.80%, the wilting point (WP) values between 17.05 - 23.05% and the bulk density values between 1.14 - 1.47 g/cm³. The soil textures were found to be clay-loam, clay, loam and sandy-clay-loam.

TABLE 3
PHYSICAL PROPERTIES OF THE SOILS TAKEN FROM THE RESEARCH AREA

Soil sampling site		Saturation (%)	Field Capacity (Volume %)	Wilting Point (Volume %)	Available water	Bulk Density (g/cm³)	Soil Texture			
Well-Plot no	Depth (cm)						Sand %	Clay %	Silt %	Texture
16	0-30	46	30,25	20,95	9,50	1,26	40,78	35,79	23,43	Clay Loam
	30-60	45	31,10	22,09	9,01	1,36	38,15	40,66	21,19	Clay
	60-90	47	32,20	23,05	9,15	1,47	32,57	41,98	25,48	Clay
19	0-30	48	29,15	17,05	12,10	1,14	49,55	21,14	29,31	Loamy
	30-60	47	29,70	19,60	10,10	1,20	51,09	21,36	27,55	Sand Clay Loam
	60-90	55	32,05	19	13,05	1,20	49,61	21,36	29,33	Loamy
20	0-30	51	31,03	19,53	11,50	1,43	40,78	30,35	28,87	Clay Loam
	30-60	52	31,20	20,15	11,05	1,14	36,0	32,75	31,25	Clay Loam
	60-90	52	32,80	19,65	13,15	1,26	42,35	28,29	28,86	Loamy

Chemical analyses were also performed on soil samples taken from the lands irrigated with five separate wells in the research area and the results are provided in Table 4. The pH values of the soils were measured as between 7.94 - 9.10, while the EC values were measured as between 242 - 857 µmhos/cm. Based on the salinity threshold value (4000 µmhos/cm) for all soil layers, it was determined that there was no salinity problem in the soils. The cation exchange capacity (CEC) values of the soil samples ranged from 15.02 to 25.17 me/100 g, while the exchangeable sodium percentages (ESP) ranged from 1.74 to 3.36. It was determined that the ESP was below the threshold value of 15%. The calcium carbonate content of the soil samples ranged from 1.74 to 33.59 and the boron concentrations ranged from 0.17 to 0.26 ppm. It was observed that the boron concentrations were below the threshold value of 4 ppm.

Based on analysis results of the research site provided in Table 4, the EC-Depth relationships are presented in Figure 9.

TABLE 4
CHEMICAL PROPERTIES OF THE SOILS TAKEN FROM THE RESEARCH AREA

Soil Sampling Site: Plot No	Soil Sampling Site: Depth (cm)	pH	EC x 10^6 µmhos/cm 25ºC	Water-Soluble Cations (me/L): Na^+	Water-Soluble Cations (me/L): K^+	Water-Soluble Cations (me/L): Ca^{+2}	Water-Soluble Cations (me/L): Mg^{+2}	Water-Soluble Cations (me/L): Total	Water-Soluble Anions (me/L): CO_3^{-2}	Water-Soluble Anions (me/L): HCO_3^-	Water-Soluble Anions (me/L): Cl^-	Water-Soluble Anions (me/L): SO_4^{-2}	Water-Soluble Anions (me/L): Total	CEC (me/100gr)	Exchangeable Sodium: Na^+	ESP (%)	Lime (%)	Boron (ppm)
2	0-30	8,07	671	1,87	1,03	3,76	0,09	6,66	-	1,5	0,5	4,45	6,45	16,57	0,54	3,25	9,86	0,24
	30-60	8,05	566	1,06	0,48	3,33	0,60	5,47	-	2	0,5	3,17	5,67	19,51	0,45	2,30	7,29	0,22
	60-90	8,00	857	1,02	0,54	5,65	1,01	8,22	-	1	0,5	6,02	7,52	20,80	0,48	2,30	7,15	0,19
7	0-30	7,94	502	0,78	0,19	3,17	0,80	4,94	-	2	-	2,72	4,72	24,88	0,51	2,04	2,57	0,17
	30-60	8,12	310	0,50	1,13	1,12	0,50	3,25	-	1	-	2,65	3,65	23,08	0,52	2,25	1,74	0,18
	60-90	8,02	242	1,26	0,32	1,04	0,42	3,04	-	1	-	2,24	3,24	25,17	0,44	1,74	2,86	0,17
16	0-30	8,12	488	1,37	1,17	2,11	0,86	5,51	-	1,5	-	4,13	5,63	15,17	0,51	3,36	29,16	0,21
	30-60	8,24	444	1,49	0,97	2,08	0,41	4,95	-	2	0,25	2,61	4,86	20,64	0,52	2,51	28,73	0,22
	60-90	8,17	360	1,43	0,74	1,79	0,33	4,29	-	2	0,25	2,44	4,69	19,62	0,38	1,93	33,59	0,26
19	0-30	8,32	621	0,18	1,23	3,79	0,70	5,90	-	1	0,5	4,58	6,08	16,20	0,45	2,77	9,86	0,24
	30-60	8,34	528	0,24	1,00	3,31	0,47	5,02	-	1,5	0,25	3,27	5,02	15,20	0,46	3,02	9,72	0,25
	60-90	8,10	570	0,94	1,29	2,34	0,79	5,36	-	1,5	0,25	3,86	5,61	15,02	0,45	2,99	11,01	0,23
20	0-30	9,10	404	1,07	0,44	2,91	0,16	4,58	-	1,5	0,5	2,18	4,18	16,68	0,54	3,23	14,01	0,21
	30-60	8,37	590	1,04	0,43	3,97	0,13	5,57	-	1	0,25	4,22	5,47	16,49	0,55	3,33	14,44	0,21
	60-90	8,10	413	0,57	0,31	3,12	0,10	4,1	-	3	-	1,32	4,32	15,60	0,50	3,20	13,72	0,21

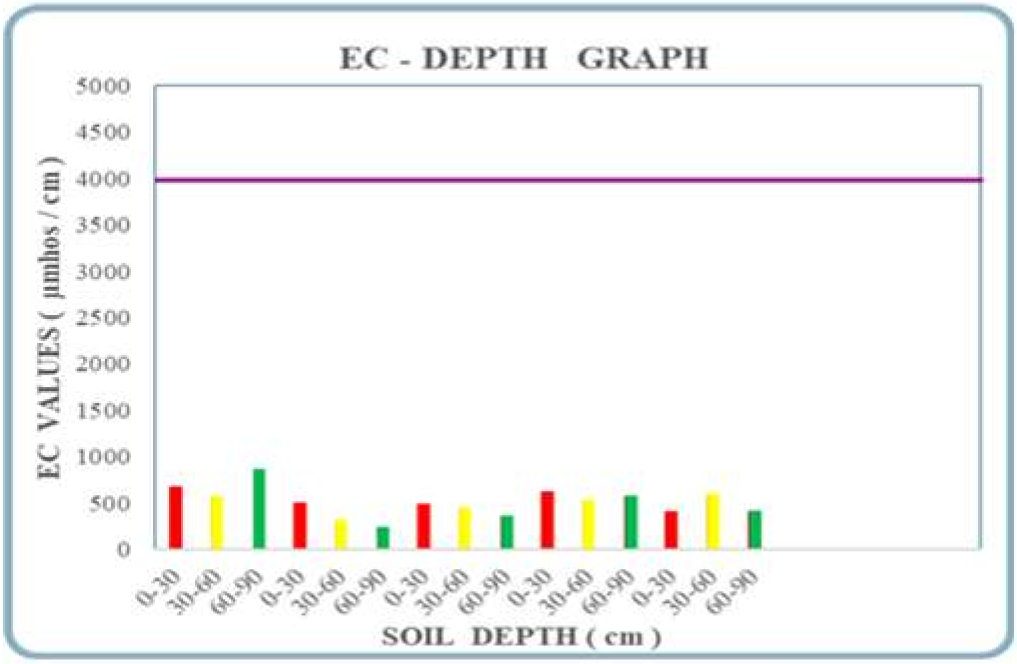


FIGURE 9: Soil EC-Depth relationships

It was observed when the EC values of soil samples taken at different depths were examined that the EC values at depths of 0-30, 30-60 and 60-90 cm were generally between 242 and 857 µmhos/cm (Figure 9). It was found that the EC values of the analyzed agricultural lands and irrigation waters were not high enough to cause salinity. The absence of salt accumulation in the soil is also an indication of salt leaching.

Considering the salt levels in the soil and water in the research area, it can be said that all kinds of agricultural production can be carried out. Measurements taken in the area showed that the boron concentration was less than 4 ppm, which indicates that there is no boron toxicity. All kinds of plants that are sensitive to boron can be grown in the area.

Based on the results of the analyses conducted in the research area, soil ESP-Depth relationships are presented in Figure 10. It was observed that ESP values did not vary with the depth. It was determined that the soil ESP values were below the threshold value of 15%.

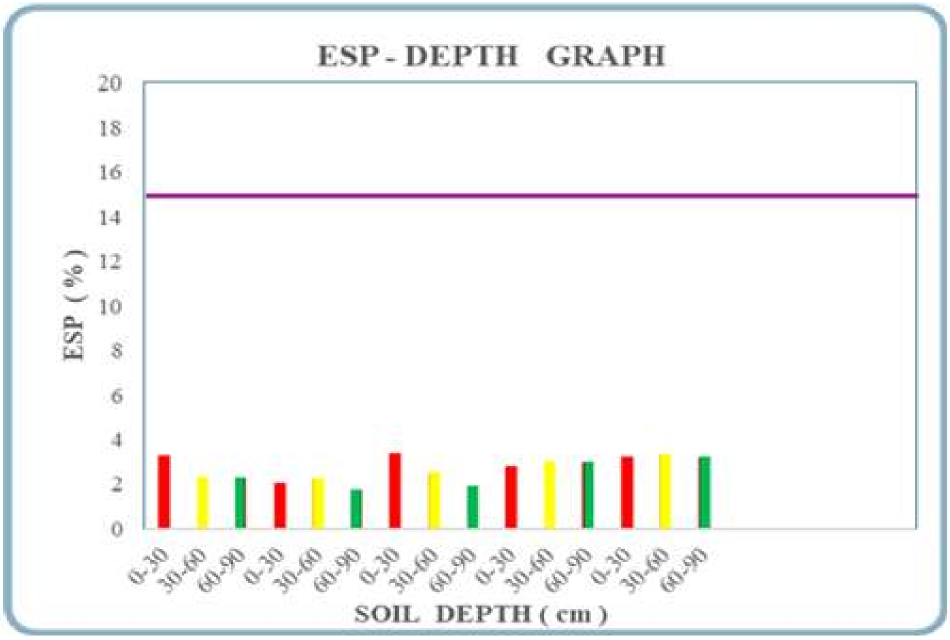


FIGURE 10: Soil ESP-Depth relationship

IV. CONCLUSION AND RECOMMENDATIONS

The results obtained from this study, conducted in Hatunsaray Neighborhood of Meram District of Konya Province to determine the salinity and alkalinity of irrigation water used in agriculture and agricultural lands are summarized below.

4.1 Conclusion:

1) The EC values of water samples taken from irrigation wells were below 750 µmhos/cm. Due to the medium salinity of the water (C_2), it can be said that the water samples were suitable for agricultural irrigation in terms of salinity. In agricultural fields irrigated with irrigation water samples (C_3) that exceed a threshold salinity value, salt-tolerant plants should be preferred and special measures may be required to control salinity. It was observed that EC values ranged from 198 to 772 µmhos/cm, while pH values ranged from 6.91 to 8.38. Based on present analyses, irrigation water was classified as C_2S_1 (moderately saline - low alkaline).
2) For water-soluble anions and cations, it can be said that water samples were rich in Ca cation and HCO_3 anion. Sodium adsorption ratios (SAR) ranged from 0.32 to 1.79. Na% values ranged from 11.0 to 31.1 and boron concentrations ranged from 0.289 to 0.417 ppm. It was determined that irrigation water samples were all below the threshold boron concentration 0.7 ppm. The boron values of the irrigation water were also reflected in the soil samples and no boron toxicity was observed in the soils.
3) In the research area, the salinity levels of irrigation water were found to be moderately saltine. Water samples taken from some irrigation wells in September and October exceeded salinity threshold value of 750 µmhos/cm, which could cause salinity problems in agricultural lands where this water is used.
4) In this study, chemical analyses of the soils were performed. The pH values of the soils ranged from 7.94 to 9.10 and the EC values ranged from 242 to 857 µmhos/cm. The cation exchange capacity (CEC) was found to be between 15.02–25.17 me/100 g, the exchangeable sodium percentage (ESP) values varied between 1.74–3.36%, the lime percentages varied between1.74 – 33.59% and the boron concentrations ranged from 0.17 to 0.26 ppm. Soil boron concentrations were below the threshold boron concentration of 4 ppm.
5) hysical analyses of the soils were also conducted. It was determined that most of the soils were loamy (L) and clay-loam (CL) in texture, with soil saturation percentages of between 45 - 55 and bulk densities of between 1.14 - 1.47 g/cm^3.
6) Soil ESP values were below the threshold value of 15%.

4.2 Recommendations:

1) Drainage systems should be installed to prevent salinity problems in agricultural areas. Maintenance and repairs of existing drainage channels must be carried out periodically.
2) Soils should be cultivated using appropriate techniques and enriched with organic matter.
3) It is likely that salinity and alkalinity problems will arise in the coming years because of climate change-induced decrease in precipitations and the increased need for irrigation water. Therefore, it is important to prioritize leaching and reclamation efforts from now on.
4) To prevent yield losses in agricultural production, the irrigation water required by the crop must be provided using appropriate methods. Considering the limited water availability, sprinkler and drip irrigation methods should be preferred in the region. The number of irrigations and the amount of water applied should be planned to avoid unnecessary and excessive irrigation.
5) Considering that irrigation water is decreasing day by day, relevant institutions and educational institutions have important tasks in training farmers about irrigation methods and providing them with information on irrigation water applications and ways to increase irrigation efficiency.
6) A detailed soil survey should be conducted within the scope of Konya Province and inventory reports should be prepared. The inventory reports, which are quite old, should be updated.

7) The absence of salinity, alkalinity and boron problems in both irrigation water and soil samples in the research area does not mean that these problems will not occur in the future. Therefore, even if reclamation studies are not carried out at an advanced level, leaching and soil physical property improvement studies should be carried out.

8) Although there are no current issues in the research area, ensuring the supply of high-quality irrigation water to fields in nearby regions where salinity, alkalinity and boron problems are present or may arise is of great importance. Therefore, further development of projects such as the KOP project would be beneficial.

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Genotypic and Phenotypic Correlation and Path Analysis for Growth and Yield Contributing Traits in Bread Wheat (*Triticum aestivum* L.)

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Abstract— *Thirty-eight advanced bread wheat lines were evaluated in Randomised Block Design with four replications at Agriculture Research Station, S. D. Agricultural University, Ladol (Gujarat) during rabi 2020-21 season to evaluate the association of yield and yield-related traits and determine the direct and indirect effects of yield-related traits on grain yield. The results of the study's correlation analysis showed grain yield per plot had highly significant and positive correlation with number of effective tiller per meter and biological yield per plot at both genotypic and phenotypic level, that indicated that these are major contributors for increasing the grain yield per plot and selection could be more effective for these traits. The estimates of genotypic correlation coefficient were higher for most of the characters than phenotypic correlation coefficient, indicating a strong inherent association among various characters. Path analysis revealed that the biological yield per plot followed by spike length had the highest positive direct effect on grain yield per plot whereas number of effective tillers per meter followed by 1000 grain weight and number of grain per spike revealed negative high direct effect on grain yield per plot. Hence, the present investigation can be helpful as selection criteria to increase grain yield in bread wheat based on these above-mentioned traits viz., biological yield per plot and spike length. These character have to be rank the first in any breeding program to improve wheat grain yield.*

Keywords— Correlation, path analysis, genotypic, phenotypic.

I. INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is one of the most crucial staple crops in the world, with a rich history dating back thousands of years. Its journey from ancient times to the present day has witnessed significant transformations in cultivation, breeding, and utilization. The mid-20th century witnessed a transformative phase in wheat cultivation with the advent of the Green Revolution. Scientists like Norman Borlaug developed high-yielding wheat varieties, leading to increased global wheat production. This revolution significantly impacted food security and helped alleviate hunger in many parts of the world. In recent decades, advancements in molecular genetics and biotechnology have revolutionized wheat breeding. Researchers have focused on developing varieties with improved yield, disease resistance, and nutritional content. Genetic modification and genome editing techniques are being explored to enhance wheat's adaptability to changing environmental conditions.

Globally wheat occupies an area of 222.11 million hectares with production of 778.6 million metric tonnes and productivity is 3.51 t/ha (OECD/FAO 2021/22). Wheat is cultivated in almost all the states of India but its extensive cultivation is confined to Uttar Pradesh, Madhya Pradesh, Punjab, Haryana, Rajasthan, Bihar and Gujarat. In India wheat occupies an area of 31.13 million hectares under irrigation with production of 109.59 million tonnes and productivity is 3.52 t/ha (Directorate of Economics and Statistics, DAC and FW 2021/22). While, In Gujarat wheat occupies an area of 1.3 million hectares with production of 4.3 million tonnes and productivity is 3156.29 Kg/ha (Directorate of Agriculture, Gujarat State 2020-21). Wheat is cultivated under irrigated as well as rainfed conditions. The eight-fold increase in wheat production (10.40 million tonnes in

1965-66 to 109.59 million tonnes in 2021/22) (Directorate of Economics and Statistics, DAC and FW 2019-20) during the last five decades has been a remarkable and unparalleled achievement.

Transcriptomic studies have shown that over 30000 genes are expressed in the developing wheat grain (Wan *et al.,* 2008) while, proteomic analysis of mature grain has revealed the presence of about 1125 individual components (Skylas *et al.*, 2000).

The study of different characters and their relationship with other is an important criterion design to break genetic barriers of yield. Whereas, correlation studies are helpful in determining the component of a complex trait *i.e.* grain yield. However, they do not provide an exact magnitude of direct and indirect effect towards the yield. Therefore, path coefficient analysis is an important tool to partition the correlation coefficient into direct and indirect effect of the independent variables on the dependent variables.

II. MATERIAL AND METHOD

The experiment was conducted on "Genotypic and Phenotypic Correlation and Path Analysis for Growth and Yield Contributing Traits in Bread Wheat (*Triticum aestivum* L.)" in *rabi* 2020-21 at Agricultural Research Station, Sardarkrushinagar Dantiwada Agricultural University, Ladol. The centre is located between latitudes 230 38' and 230 41' N and longitudes 720 41' and 720 44' E. *Triticum aestivum* L. (bread wheat) genotypes (Table 1) representing 38 different genetic origins used as the experimental material for this study. These taken from the S.D.A.U. Wheat Research Station in Vijapur, Gujarat. Four replications of the current experiment were done using a Randomized Block Design (RBD). Each genotype has a double row that is 3.0 meters long and spaced 22.5 cm apart. Twelve different traits, including days to heading (N), days to maturity (N), plant height (cm), effective tillers per meter, number of grains per spike, spike length (cm), grain yield per plot (g), biological yield per plot (g), harvest index (%), 1000 grain weight (g), protein content (%), and sedimentation value (ml), were observed for this investigation. Except for the traits of days to heading (N), days to maturity (N), number of effective tillers per meter, grain yield per plot (g), biological yield per plot (g), harvest index (%), 1000 grain weight (g), protein content (%) and sedimentation value (ml), observations were made on five randomly chosen plants from each replication. Phenotypic and genotypic correlation were estimated using the standard procedure suggested by Dewey and Lu. Path coefficient analysis was performed for character that had significant correlations with grain yield both at genotypic and phenotypic levels in order to know the direct and indirect effect of yield character on grain yield using the general formula of Al-Jibouri *et al.* by considering grain yield per plot as dependent variable.

TABLE 1
LIST OF GENOTYPES

Sr.No.	Genotypes	Sr.No.	Genotypes
1	ABV 2019-23	20	36th SAWSN-3002
2	ABV 2019-39	21	36th SAWSN-3047
3	ABV 2019-48	22	36th SAWSN-3048
4	ABV 2019-50	23	36th SAWSN-3073
5	ABV 2019-68	24	36th SAWSN-3129
6	VA 2016-22	25	36th SAWSN-3261
7	VA 2019-04	26	29th HRWSN-2040
8	VA 2019-05	27	29th HRWSN-2054
9	VA 2019-06	28	29th HRWSN-2129
10	VA 2019-16	29	DBW-187
11	VA 2019-18	30	DBW-222
12	HI-1633	31	MP-1203
13	HI-1634	32	MP-1338
14	Raj-3065	33	RWP 2018-29
15	Raj-3777	34	CG-1029
16	Raj-4079	35	WH-730
17	Raj-4083	36	LOK 1
18	17thHTWYT-38	37	GW 322
19	17th HTWYT-49	38	GW 451

III. RESULTS AND DISCUSSION

Complete knowledge on interrelationship of grain yield with other character is of paramount importance to the breeder for making improvement in complex quantitative character like grain yield for which direct selection is not much effective. Hence, mutual relationship was undertaken to determine the direction of selection and number of characters to be considered in improving grain yield. Genotypic correlation coefficient in general were higher than phenotypic correlation coefficient indicating strong inherent association between the traits.

Table 2 shown the phenotypic and genotypic relationships for morpho-agronomic features. At both the genotypic and phenotypic levels in the current study, there was a highly significant and positive correlation between grain yield per plot and the number of effective tillers per meter (rg = 0.558 and rp = 0.418) and biological yield per plot (rg = 0.919 and rp = 0.689). This showed that these traits are important for increasing grain yield per plot and that selection could be more successful for these traits. Meles et al. (2017) demonstrated a favourable and extremely significant correlation between grain yield and biological yield. At both the genotypic and phenotypic levels, the number of effective tillers per meter demonstrated a strong and positive correlation with spike length (rg = 0.345 and rp = 0.228). Grain yield per plot exhibited non-significant and negative correlation with days to maturity (rg = -0.181 and rp = -0.131), protein content (rg = -0.093 and rp = -0.020) and sedimentation value (rg = -0.015 and rp = -0.006) at both genotypic and phenotypic level. Days to heading displayed both genotypic and phenotypic non-significant and positive correlation with tillers per meter (rg = 0.105 and rp = 0.075). These findings are consistent with those made earlier (Anwar et al. 2009). At the genotypic level, there was a strong and positive correlation between grain yield per plot and 1000 grain weight (rg = 0.311) and number of grains per spike (rg = 0.322). Similar results were first noted by Khaliq et al. (2004).

An efficient method for identifying both direct and indirect origins of correlations is path coefficient analysis. The results are given in Table 3 and figure 1, which show that the biological yield per plot had the most positive direct influence, followed by the days to heading, spike length, plant height, harvest index, days to maturity and protein content. Ayer et al. (2017) and Rajput, R. (2019) both reported on high positive direct effects of biological yield on grain production per plot. Plant height had a positive and negligible indirect influence that was measured by days to maturity (0.027), effective tillers per meter (0.018), grains per spike (0.061), biological yield per plot (0.045), 1000 grain weight (0.050), protein content (0.026) and sedimentation value (0.031). The direct impact of effective tillers per meter on grain yield per plot was very large (-2.073) and negative. Grain yield per plot was directly affected positively and significantly (0.441). The indirect impact of 1000 grain weight was positive and negligible, as measured by the number of effective tillers per meter (0.007) and spike length (0.047). Positive and small (0.060), the direct impact of protein content on grain yield per plot. Through the number of effective tillers per meter (-0.028), the number of grains per spike (-0.058), and the biological yield per plot (-0.088), sedimentation value showed a detrimental and negligible indirect influence.

There is a significant intrinsic relationship between different characters, as evidenced by the estimations of genotypic correlation coefficient being larger than phenotypic correlation coefficient for the majority of the characters. The results of the study's correlation analysis showed that at both the genotypic and phenotypic levels, the grain yield had a high and positive association with the number of efficient tillers per meter and the biological yield per plot. According to path analysis studies, biological yield per plot, days to heading, spike length, plant height, harvest index, days to maturity and protein content all had a positive and direct impact on grain production per plot. Based on the results, it would be reasonable to recommend that a breeder working to increase bread wheat's grain yield emphasise the traits 1000 grain weight, number of effective tillers per meter, grain yield per plot, biological yield per plot, harvest index, spike length, and number of grains per spike. Therefore, choosing individuals with these qualities will immediately aid in boosting bread wheat's grain yield.

TABLE 2
GENOTYPIC CORRELATION AND PHENOTYPIC CORRELATION COEFFICIENT FOR DIFFERENT CHARACTERS IN BREAD WHEAT

Character		DH	DM	PH	TIL/M	SL	NGS	BYP	HI	TGW	PC	SV	GYP
DH	r_g	1											
	r_p	1											
DM	r_g	0.468**	1										
	r_p	0.437**	1										
PH	r_g	-0.029	0.102	1									
	r_p	-0.028	0.077	1									
TIL/M	r_g	0.105	0.107	0.069	1								
	r_p	0.075	0.089	0.070	1								
SL	r_g	-0.008	-0.125	-0.094	0.345*	1							
	r_p	-0.016	-0.073	-0.099	0.228**	1							
NGS	r_g	-0.045	0.082	0.232	-0.277	-0.271	1						
	r_p	0.018	0.032	0.198*	-0.135	-0.122	1						
BYP	r_g	-0.112	-0.024	0.171	0.793**	0.054	0.139	1					
	r_p	-0.071	0.013	0.178*	0.601**	0.108	0.222**	1					
HI	r_g	-0.359*	-0.566**	-0.520**	-0.037	-0.003	-0.013	0.077	1				
	r_p	-0.256**	-0.370**	-0.295**	-0.006	0.057	0.039	0.065	1				
TGW	r_g	-0.531**	-0.169	0.189	0.039	-0.060	0.035	0.131	0.012	1			
	r_p	-0.496**	-0.149	0.156	0.007	-0.033	-0.138	0.125	-0.016	1			
PC	r_g	0.624**	0.040	0.098	-0.141	-0.426**	0.080	0.041	-0.130	-0.485**	1		
	r_p	0.432**	0.048	-0.023	-0.012	-0.239**	0.006	0.005	-0.068	-0.333**	1		
SV	r_g	0.722**	0.191	0.117	0.026	-0.104	0.054	0.082	-0.097	-0.577**	0.994**	1	
	r_p	0.562**	0.131	0.048	0.013	-0.128	-0.023	-0.008	-0.068	-0.412**	0.552**	1	
GYP	r_g	-0.274	-0.181	0.024	0.558**	0.149	0.322*	0.919**	0.190	0.311*	-0.093	-0.015	1
	r_p	-0.224**	-0.131	0.020	0.418**	0.112	0.200*	0.689**	0.074	0.255**	-0.020	-0.006	1

, ** significant at 0.05 and 0.01 level of significance, respectively. Where, DH= days to heading (N), DM= days to maturity (N), PH= plant height (cm), TIL/M= number of effective tiller per meter, SL= spike length (cm), NGS= number of grain per spike, BYP = biological yield per plot (g), HI = harvest index (%), TGW = 1000 grain weight (g), PC = protein content (%), SV = sedimentation value (ml) and GYP = grain yield per plot (g)

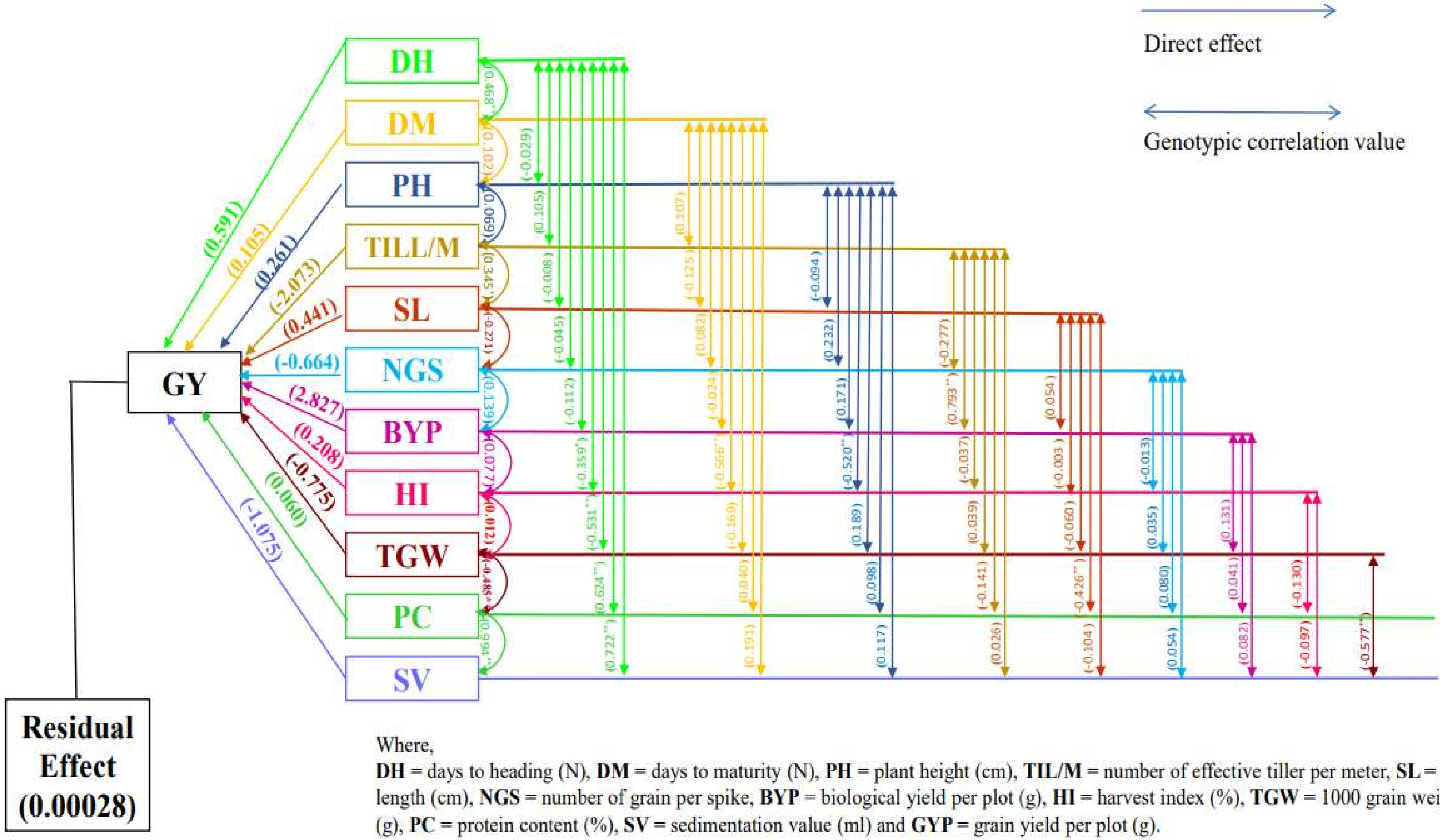
TABLE 3
DIRECT AND INDIRECT EFFECTS OF YIELD COMPONENT ON GRAIN YIELD IN BREAD WHEAT

Character	DH	DM	PH	TIL/M	SL	NGS	BYP	HI	TGW	PC	SV	Genotypic correlation with GYP
DH	**0.591**	0.049	-0.007	-0.217	-0.003	0.030	-0.317	-0.075	0.414	0.038	-0.776	-0.274
DM	0.276	**0.105**	0.027	-0.222	-0.055	-0.055	-0.068	-0.118	0.132	0.002	-0.205	-0.181
PH	-0.017	0.011	**0.261**	-0.144	-0.042	-0.154	0.485	-0.108	-0.147	0.006	-0.126	0.024
TIL/M	0.062	0.011	0.018	**-2.073**	0.152	0.184	2.242	-0.008	0.007	-0.009	-0.028	0.558**
SL	-0.004	-0.013	-0.025	-0.714	**0.441**	0.180	0.153	-0.001	0.047	-0.026	0.112	0.149
NGS	-0.027	0.009	0.061	0.574	-0.119	**-0.664**	0.394	-0.003	0.151	0.005	-0.058	0.322*
BYP	-0.066	-0.003	0.045	-1.644	0.024	-0.092	**2.827**	0.016	-0.102	0.003	-0.088	0.919**
HI	-0.212	-0.059	-0.136	0.077	-0.001	0.009	0.218	**0.208**	-0.009	-0.008	0.104	0.190
TGW	-0.315	-0.018	0.050	0.017	-0.027	0.130	0.371	0.002	**-0.775**	-0.029	0.620	0.311*
PC	0.369	0.004	0.026	0.292	-0.188	-0.053	0.117	-0.027	0.376	**0.060**	-1.068	-0.093
SV	0.426	0.020	0.031	-0.054	-0.046	-0.036	0.232	-0.020	0.447	0.060	**-1.075**	-0.015

, ** significant at 0.05 and 0.01 level of significance respectively. (Residual effect = 0.00028)

Where,

DH = days to heading (N), DM = days to maturity (N), PH = plant height (cm), TIL/M = number of effective tillers per meter, SL = spike length (cm), NGS = number of grain per spike, BYP = biological yield per plot (g), HI = harvest index (%), TGW = 1000 grain weight (g), PC = protein content (%), SV = sedimentation value (ml) and GYP = grain yield per plot (g)



Where,

DH = days to heading (N), **DM** = days to maturity (N), **PH** = plant height (cm), **TIL/M** = number of effective tiller per meter, **SL** = spike length (cm), **NGS** = number of grain per spike, **BYP** = biological yield per plot (g), **HI** = harvest index (%), **TGW** = 1000 grain weight (g), **PC** = protein content (%), **SV** = sedimentation value (ml) and **GYP** = grain yield per plot (g).

FIGURE 1: Genotypical path diagram for grain yield per plot

FIGURE 2: General view of experimental site

IV. CONCLUSION

The estimates of genotypic correlation coefficient were higher for most of the characters than phenotypic correlation coefficient, indicating a strong inherent association among various characters. The results of the study's correlation analysis showed that at both the genotypic and phenotypic levels, the grain yield had a high and positive association with the number of efficient tillers per meter and the biological yield per plot at both genotypic and phenotypic level. The grain yield showed significant positive correlation with number of grain per spike and 1000 grain weight at both genotypic and phenotypic level. This has been indicating that more attention should give to this character to improve the grain yield of bread wheat. According to path analysis studies revealed that positive and direct effect towards grain yield per plot was observed by biological yield per plot, days to heading, spike length, plant height, harvest index, days to maturity and protein content, whereas number of effective tiller per meter, sedimentation value, 1000 grain weight and number of grain per spike had showed negative direct effect on grain yield per plot. Thus, characters biological yield per plot, days to heading, spike length, plant height, harvest index, days to maturity and protein content turned out to be the major components traits for grain yield per plot and direct selection for these traits will be rewarded for improvement of grain yield in wheat. Therefore, choosing individuals with these qualities will immediately aid in boosting bread wheat's grain yield. The Residual effect in path coefficient analysis was low indicating a high contribution of independent traits to the dependent trait.

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Biogas Production from Hog and Poultry Manure Substrates using Plastic Drum Biogas Digester during Night and Daytime Collection

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***Abstract*—** *Plastic drum biogas digester (PDBD) is a low-cost yet an efficient system in biogas production using different manure substrates as feedstock. Hence, this study was conducted to determine the volume of biogas produce using the PDBD system in daytime and nighttime collection using swine slurry (SS) and chicken manure (CM) as substrates. Likewise, to assess the economic feasibility of the low-cost biogas system. A 8-drum PDBD system was designed, fabricated and immersed in the manure or slurry lagoon of private piggery and poultry farms in Science City of Munoz, Nueva Ecija and San Antonio, Quezon Province, Philippines, respectively. The captured methane gas produced was observed and measured during day and night times. The volume of gas produced after 96 hours (4 days) was 2,580.64 ℓ or 1316.65 kg which tested 4 hours of uninterrupted cooking or a flow rate of 10.98 ℓ/minute using the system with SS. While, 8,856.72 ℓ which when allowed to a continuous depletion or emptying the submersion of the PDBD, the recorded time consumed was 16.5 minutes through a double burner stove with maximum level of fire using the PBDB system with CM. Higher methane captured was recorded during daytime compared to nighttime in both SS and CM substrate using the PDBD system. Lastly, the PDBD system is economically feasible. The PBDB system has proven to capture biogas or methane in an open-pit lagoon with minimal cost of production and economically viable to invest and include in a swine and poultry enterprises.*

***Keywords*— A Biogas, Chicken Manure, Methane and Swine Manure.**

I. INTRODUCTION

Livestock and poultry production are significant contributors to greenhouse gas emission particularly the volatilization of methane from the manure. Moreover, methane has 23 times global warming potential compared to carbon dioxide (Phillippe et al., 2007), hence strategies for methane capture would be indispensable towards mitigating the adverse effects of climate change. The biogas digester is an appropriate design towards preventing methane emission. As a matter of fact, the use of biogas as effective farm equipment is an excellent example of sound integrated crop and livestock management. Waste from livestock such as cattle, swine and poultry can be utilized as a renewable energy source which is the biogas. Moreover, biogas sludge can be applied to crops and in ponds as source of organic fertilizer. Likewise, biogas technology will solve environmental pollution and convert livestock waste into energy, savings or income (Largo, 2012).

Presently, because of the scarcity of resources and a worldwide market competition, the hike in price of some market product is continuously increasing, and because of this, people tend to find alternatives that are lower energy cost. The search for alternative sources of non-fossil based energy has all the more been very relevant than now due to its substantial positive impact on climate change. Moreover, the use of biogas as alternative to LPG is environment friendly.

The construction of biogas facility such as the fixed dome is quite expensive due to prohibitive cost of cement, steel bars and labor. It is on this premise, that the Plastic Drum Biogas Digester (PDBD) was tested to demonstrate its techno-viability for possible prototyping and subsequently techno-commercialization. This has unique features, which include: 1) production of biogas in an open pit lagoon (unlike the fixed dome digester); 2) production of odorless CH4 gas; and 3) conversion of the biogas sludge into an organic fertilizer. Moreover, the PDBD is simple, practical, low cost, versatile, maintenance free and can be readily replicated by backyard and commercial pig farmers (Barroga, 2015). The latter researchers claimed that a four 200 - ℓ PDBD from an 8 sow level farm recorded a biogas production of 710.43 - ℓ with a flow rate of 5.92 - ℓ/minute. The savings derived with the use of biogas instead of the LPG is PhP 16.90/ℓ. The ROI was 103.30% with a Marginal Benefit Cost Ratio of 1.28 and a Payback Period of 0.97 year indicating that investing in the PDBD was financially viable. Lastly, this system of biogas production is considered novel because the plastic drum can serve as a mixer, digester floater, aerobic fermentation chamber, ammonia neutralizer, desulphizer, composting vat and a processor of a rich nutrient packed odorless effluent or pig liquid fertilizer. Hence, this study was conducted to determine the dynamics of biogas production using different animal manure substrates in day and night collection.

II. MATERIALS AND METHOD

The study was conducted in two separate locations relative to the substrate used in biogas production. For the poultry manure as substrate, it was conducted in the poultry manure lagoon of a 248,000 broiler tunnel ventilated house in Barangay San Jose, Quezon Province. While, the for the pig manure, it was conducted at ELR Family Trading Co. Inc., Brgy. Bagong Sikat, Science City of Muñoz, Nueva Ecija. The biogas flow monitoring and data collection was simultaneously done in both locations from April to May, 2017.

2.1 Experimental Setup:

The PDBD was fabricated and composed of eight 200 - ℓ plastic drum with an open bottom and a gas collection fitting above to facilitate extraction of biogas towards the cooking stove. The eight plastic drums were linked with a strong nylon thread and tied to a stable post to ensure stability during the daily biogas accumulation. This is because there was an alternate rise and fall of the floating drum when cooking is periodically done daily. The PBDB system was immersed in the poultry waste lagoon measuring 463.6 cubic while, open pit septic tank for the swine slurry. Furthermore, Odor Erasing Microbial Concoction (OEMC) was top-dressed at 5 grams per m2 twice-weekly basis in the open lagoon and open septic tank. The time of monitoring and measuring the volume of biogas production which is day time (DT) and night time (NT) served as treatments of the study. Data for total gas production from night-time and day-time collection, flow rate per minute, ℓ and depletion time per 6 inch, was replicated 4 times.

2.2 Data Gathered:

The data collected include: 1) quantity of volume of biogas trapped; 2) profitability and viability of PDBD; and 3) assess environmental impact of the PBDB. The quantity of volume of biogas trapped was expressed in: a) period to full capacity in hour, which was computed by the number of hours consumed when the PDBD is in full capacity; b) total volume of methane captured per drum computed through the formula, c) total volume of methane captured/drum = 200 ℓ x % elevation/drum ÷ 100 % ; d) flow rate, ℓ/minute computed as, flow rate/ minute = total volume of methane, ℓ/drum / time consume till full depletion, minute; and e) period every 6-inch depletion /minutes calculated as total time consumed in ℓ for every 6 inch depletion of the PDBD (a total of five six inch depletions was recorded as the length of the plastic drum is 30 inches in length). The profitability and viability of PDBD was expressed in terms of the cost to produce per ℓ of biogas, in pesos. Lastly, the economic efficiency was expressed through: return on investment, %; payback period, year; and marginal benefit cost ratio in pesos.

III. RESULTS AND DISCUSSION

3.1 Volume of Collected Biogas at Day and Night Time on Swine Manure Substrate:

Table 1 shows the comparative periodic increase in height in inch of the PDBD when collected during daytime and night-time for four consecutive days. During daytime collection, the mean elevation of the PDBD was 27.43 ± 0.28 inches while at night-time collection, it was only 15.48 ± 0.21 or a reduction rate of 43.58%. The data indicated that the DT collection of biogas resulted to a significantly ($p<0.05$) faster conversion of the slurry into biogas fuel. Therefore, the PDBD was filled up with biogas more rapidly during daytime than night-time. The faster collection of biogas at daytime apparently support the claim that biogas production can be influenced by several factors namely; 1. substrate 2. pH 3. C/N ratio and, 4. presence of inhibitory substances such as detergents, antibiotics, and antiseptic. Moreover, temperature has a strong influence over the quality and quantity of biogas production (Dobre et al., 2014). Therefore, the rapid filling up of the PDBD at daytime could be due to the activation of the Thermophilic bacteria for methane gas conversion considering that the parameter daytime temperature was higher than night-time temperature.

TABLE 1
PERIODIC INCREASE IN HEIGHT (INCH) OF THE PDBD, RELATIVE TO TIME OF COLLECTION

Day	DT	NT
1	26.70	15.00
2	28.00	16.00
3	27.70	15.40
4	27.30	15.50
Mean	27.43 ± 0.28[a]	15.48 ± 0.21[b]

DT = Daytime, 12 hours biogas collection from 6:00 AM to 6:00 PM for 4 consecutive days
NT = Night-time, 12 hours biogas collection from 6:00 PM to 6:00 AM for 4 consecutive days
DT and NT means are significantly different based on t-test ($p < 0.05$)

The comparative volume in liters of biogas captured by PDBD relative to collection time is shown in Table 2. Results showed that during the 4-day collection period, the total volume of the biogas collected at daytime was 1415.48 ± 14.49 while the total volume of biogas collected at night-time was 798.70 ± 10.63. The higher volume produced during daytime collection was consistent and related also to the higher elevation of the PDBD at daytime compared to night time. The conversion value of the volume of biogas trapped to CH4 gas in kg is 0.45 or is equivalent to 0.45 kg CH4 gas, therefore the 1415 ℓ biogas captured by the PDBD in the present study when converted to kg CH4 gas is 1.415 m3 (1000 ℓ biogas trapped = 1 m3 biogas trapped) multiplied by 0.45 was equivalent to 0.637 kg CH4 gas or 637 ℓ of CH4 gas.

TABLE 2
COMPARATIVE VOLUME OF BIOGAS CAPTURED BY PDBD RELATIVE TO COLLECTION TIME

Day	DT			NT		
	PDBD height (inch)	Calculated volume (ℓ)	Total volume (ℓ)	PDBD height (inch)	Calculated volume (ℓ)	Total volume (ℓ)
1	26.70	172.26	1378.08	15.00	96.77	774.16
2	28.00	180.64	1445.12	16.00	103.23	825.84
3	27.70	178.71	1429.68	15.40	99.35	794.80
4	27.30	176.13	1409.04	15.50	100.00	800.00
Mean	27.43 ± 0.28	176.94±1.81	1415.48±14.49	15.48±0.21	99.84±1.33	798.70±10.63

DT: Daytime collection; 6:00 AM – 6:00 PM
NT: Night-time collection; 6:00 PM – 6:00 AM
Formula: Calculated volume of biogas, ℓ = 200 ℓ x % elevation/drum

3.2 Duration of Flaring and Flow Rate of Biogas from Swine Manure:

The comparative duration of flaring of CH4 gas collected by the PDBD at DT and NT is shown in Table 3. Result disclosed that flaring duration at DT collection is 161.25 minutes and was 46.82% longer than NT collection with only 85.75 minutes. Therefore, the 8-drum PDBD is sufficient to serve the daily cooking fuel requirement of a single household of 5, with the DT collection being recommended as flaring time is equivalent to 161.25 ± 1.38 minutes or 2 hours and 65 minutes per day.

TABLE 3
DURATION OF CONTINUOUS CH_4 GAS FLOW BY TWO-BURNER GAS STOVE, MINUTES

Day	DT[1]		NT[2]	
	Total volume[3] (ℓ)	Flaring[4] (minutes)	Total volume (ℓ)	Flaring (minutes)
1	1378.08	158	774.16	84
2	1445.12	164	825.84	88
3	1429.68	163	794.80	85
4	1409.04	160	800.00	86
Mean	1415.48 ± 14.49	161.25 ± 1.38[a]	798.70±10.63	85.75 ± 0.85[b]

[1]Daytime: 6:00 AM to 6:00 PM for 4 consecutive days
[2]Night-time: 6:00 PM to 6:00 AM for 4 consecutive days
[3]Equivalent to eight 200-ℓ plastic drums
[4]Allowing methane gas flow from the PDBD to a simultaneously opened 2-burner gas stove
DT and NT means are significantly different based on t-test ($p < 0.05$).

The comparative flow rate in ℓ per minute of the biogas captured by PDBD during DT and NT for an average of 4 consecutive days is shown in Table 4. The flow rate collected during NT which was 9.31 ± 0.03 ℓ/minute was slightly faster than DT with 8.78 ± 0.02 ℓ/minute. The almost similar flow rate apparently, indicated similar pressure build up inside the PDBD. This can also be attributed to the same substrates fermented by methane fermenting bacteria.

TABLE 4
COMPARATIVE FLOW RATE OF BIOGAS CAPTURED BY PDBD DURING DT AND NT, ℓ/MINUTE

Day	DT[1]			NT[2]		
	Total volume (ℓ)	Total depletion[3] (minute)	Flow rate ℓ/minute	Total volume (ℓ)	Total depletion (minute)	Flow rate ℓ/minute
1	1378.08	158	8.72	774.16	84	9.22
2	1445.12	164	8.81	825.84	88	9.38
3	1429.68	163	8.77	794.80	85	9.35
4	1409.04	160	8.81	800.00	86	9.30
Mean	1415.48±14.49	161.25±1.38	8.78±0.02	798.70±10.63	85.75±0.85	9.31±0.03

[1]Daytime: 6:00 AM to 6:00 PM for 4 consecutive days
[2]Night-time: 6:00 PM to 6:00 AM for 4 consecutive days
[3]Recorded time consumed in minutes when PDBD is almost fully submerged (see Appendix 6)

3.3 Economic Analysis of PDBD System with Swine Manure as Substrate:

Presented in Table 5 is the economic analysis of the PBDB biogas system using swine slurry as substrate. A PDBD with eight 200- ℓ units of drums has a total volume of 1600 ℓ. If the 1600 ℓ capacity of the PDBD will be filled fully with biogas, and the total cost of fabrication of it was PhP 21,860, therefore, a cost per ℓ of biogas from PDBD was PhP 13.66. The MBCR was 0.15, indicating that for every peso of variable cost of OEMC treated PDBD invested PhP 0.15 was the additional profit. On the other hand, the ROI for this project is 143.74%, which indicates that for every peso of investment, the return is equivalent to PhP 1.43. This figure is far better than other projects because it has very low investment and the return or savings is twice the amount when a commercial LPG is used. However, in this study, the cost of the manure was not included, hence in future economic evaluation of the PDBD, the cost of manure can be included. Lastly, the total investment can be recovered in 0.7 yr.

The PDBD equipment has an estimated productive life of 5 years and the only maintenance additive is the OEMC which should be regularly used to produce CH4 and is very effective in reducing ammonia and flies.

TABLE 5
ECONOMIC ANALYSIS OF BIOGAS PRODUCTION

Particulars	Economic Data
Cost to Produce per ℓ, PhP	13.66
Savings per ℓ, PhP	19.61
ROI,%	143.74
Payback Period, yr	0.7
Marginal Benefit Cost Ratio	0.15

3.4 Total Volume of Methane Captured on Poultry Manure as Substrate:

Presented in Table 6 is the total volume of methane captured by the 8-drum PBDB using chicken manure as substrate. It is consistent that more methane are captured during daytime compared to night time. Specifically, an average of 329.04 liters of biogas was captured during daytime at four-day observation period while, 316.12 liters was captured during the night time. The result is similar with the volume of methane captured on swine manure as substrate on the different observation period.

TABLE 6
PERCENT ELEVATION, VOLUME OF METHANE CAPTURED INDIVIDUAL DRUM AND IN EIGHT DRUM

	Day 1		Day 2		Day 3		Day 4		Ave.	
Parameters	DT	NT	DT	NT	DT	NT	DT	NT	DT	NT
Increase (Inches)	4.50	4.00	5.00	5.00	9.00	9.50	7.00	6.00	6.40	6.40
Percent Elevation	14.52	12.90	16.13	16.13	29.03	30.65	22.58	19.35	20.57	19.75
Volume of methane L /drum	29.04	25.80	32.26	32.26	58.06	61.30	45.16	38.70	41.13	39.52
Vol. of methane L in 8 drum	232.32	206.40	258.08	258.08	464.48	490.40	361.28	309.60	329.04	316.12

DT-Daytime; NT Nighttime

3.5 Flow Rate L/min. of Biogas from Poultry Manure:

The volume in liters of biogas consume every minutes of uninterrupted cooking is presented in a Table 7. This was proportionally calculated from the total biogas captured of the eight 200 liters drum was 2580.64 liters divided by 235 minutes which was the time consumed when biogas was fully used for cooking.

TABLE 7
COMPUTED BIOGAS FLOW RATE DAYTIME AND NIGHTTIME COLLECTION DATA

Parameters	DT	NT	DT	NT	DT	NT	DT	NT
Vol. of methane L in 8 drum	232.32	206.4	258.08	258.08	464.48	490.4	361.28	309.6
Depletion Time/ minute	22	19	24	25	44	45	33	23
Flow rate , L/ minute	10.56	10.86	10.75	10.32	10.56	10.89	10.95	13.46

3.6 Economic Analysis of PBDB System Using Poultry Manure as Substrate:

Presented in Table 8 is economic analysis of the PBDB system with chicken manure as substrate. The cost to produce per ℓ of biogas, the following were considered: fabrication cost, labor cost and the cost of the OEMC biogas additive; a total cost of PhP17, 770was calculated and this was divided by 2,580.64 ℓ, resulting to a PhP6.89cost/ ℓ of biogas. The return on investment (ROI) computed was 383.16%, which indicates that for every peso of investment, the return is equivalent to PhP 3.83. On the other hand, based on the savings and cost to produce, the total investment can be recovered in less than of a half of the year (0.26 yr). Lastly, the computed marginal cost benefit ratio was 1.18 which indicates that for every additional peso of variable costs of the biogas project, the gross return is PhP 1.18. The rule of thumb in MBCR is more than 1.0 that one project is efficient. Therefore, PDBD is an effective or efficient to invest money.

TABLE 8
ECONOMIC ANALYSIS OF BIOGAS PRODUCTION

Particulars	Economic Data
Cost to Produce per ℓ,PhP	6.89
Savings per ℓ,PhP	26.4
ROI %	383.16
Payback Period,yr	0.26
Marginal Benefit Cost Ratio	1.18

IV. CONCLUSION

The PBDB system of biogas production using two different substrates such as pig slurry and chicken manure efficiently captured and produce biogas on different observation period. On the pig slurry as substrate, it was observed that more methane are captured during daytime compared to night time and consequently, longer duration of flaring. On the hand, same flow rate was observed between the periods of observation. Similarly, almost the same observation when chicken manure is use as substrate. Lastly, the PDBD system is economically feasible regardless of the type of substrates use.

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Effect of Urea and Cocoly® Fertilizers on Production of Sugarcane (*Saccharum officianarum* L.), Kenana Sugar Scheme, White Nile State, Sudan

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***Abstract*—** *Sugarcane (Saccharum officianarum L.) is one of the most important economic crops in the world. The climatic conditions and soil types in the Sudan are suitable for the production of the crop, especially in the central clay plains. The aim of this study was to investigate the effect of different levels of Urea and Cocoly® fertilizers on yield and yield components of sugarcane (variety Co997) in the heavy clay soils. The experiment was conducted at the Research and Development Farm, Kenana Sugar Scheme (Sudan), during the season-(2021/2022). The treatments consisted of three levels of Urea fertilizer (0, 238 and 375 kg/ha) and four levels of Cocoly® fertilizer (0, 48, 95 and 143 kg/ha). The treatments were arranged in split plot design with four replications. Urea fertilizer was assigned as the main plots and Cocoly® fertilizer as the subplots. The results showed that increasing Urea fertilizer, significantly increased cane height, cane thickness, cane internodes and cane yield. Whereas increasing Cocoly® fertilizer, significantly increased plant height, stalk population, stalk weight and cane yield. The highest cane yield (199.9 t/ha) was obtained when the crop fertilized with 143 kg Cocoly®/ha and 375kg/ha Urea. Depending on the results of this study, to obtain high cane yield from Sugarcane, it could be recommended that the crop should be fertilized with 143 kg/ha of Cocoly® and 375 kg/ha of Urea.*

***Keywords*— *Cocoly® fertilizer, Sugarcane yield, Urea fertilizer, Heavy clay soils, Kenana Sugar Scheme*.**

I. INTRODUCTION

Sugarcane (*Saccharum officianarum* L.) is a tropical giant perennial grass belongs to the family poaceae that includes cereal crops such as maize, wheat, rice, sorghum and many forage crops (Jannoo *et al.,* 2007). It is cultivated for the production of sugar and as a source of bio-energy due to its phenomenal dry matter production. Demand for sugar and bio-energy is increasing day by day but its present production is not enough to meet the increasing demand. The average production is much lower than the achievable potential of the existing sugarcane varieties (Ayoub *et al.,* 1999).

Sugarcane is one of the most important economic crops and the largest sugar crop in the world. The main sugarcane growing countries include: India, Brazil, Cuba, Australia and Mexico (Morais *et al*., 2015). According to the estimates of the Food and Agriculture Organization of the United Nations, the crop was cultivated on about 23.8 million hectares, in more than 90 countries, with a worldwide harvest of 1.69 billion tons (FAO 2010). Sudan is the third-largest producer of sugar in Africa (Hassan, 2008). The country's estimated production is about 800 000 t, which is equivalent to 7.5 % of the African continent (Hassan, 2008). In Sudan, sugarcane is grown in two seasons, summer and winter (Ibrahim, 1978).

Sugarcane has been recognized as a crop with high potential that can successfully meet future sugar requirements (Hamid and Dagash, 2014). The soaring world's sugar prices in the late 1950 motivated the Government of Sudan to plan establishment of sugar industry to ease pressure on its foreign exchange reserves and create jobs and employment within a new industrial environment (Ali, 1986). El Guneid Sugar Factory was commissioned in 1962 and the New Halfa Sugar Factory in 1964, each with a sugar production capacity of 60,000 tons per annum. The two projects were established to meet the domestic demand levels that were estimated at 120,000 tons per annum. In the early seventies the Sudanese Government designed a new plan to meet the growing demand for sugar. Therefore, Three major sugar plantations were successfully constructed, Assalaya, North West Sennar and Kenana (Ali, 1986). The Sudanese sugar industry started in the early 1960s. Currently, the production capacity, designed for the existing five sugar factories, is 755,000 tons (Hussein, 2013).

Kenana Sugar Company (KSC) was established in 1979 as a private (integrated) company and started production activity in 1984 (El Nazir and Desai, 2014). While the remaining four sugar plantations were administered by the Sudanese Sugar Company (SSC), a publicly owned enterprise(Ibrahim 2020). Sugarcane production in Kenana Sugar Scheme was supported by establishment of the research and development station in order to increasing the productivity of sugarcane through the effectively fertilization programs. The soil at Kenana scheme is a heavy clay soil “vertisols” (Ali, 1986). Besides, the clay contents in these soils which range between 60 and 70% (Blokhuis, 1993), these soil are classified under Dinder series (Abdulla *et al*., 1985).

Sustainable nutrient management is considered an integral part of sugarcane production (Schroeder *et al*., 2005). Use of fertilizers play an important role in increasing sugarcane yield (Nazir *et al*., 2013).

Proper fertilization is an important management function in sugarcane production (Hasan *et al*., 2021). Balanced application of different nutrient levels produced thicker cane, longer height and higher millable canes and high cane yield (Junejo *et al*., 2014). The increasing of cane yield production found followed the trend: millable cane, cane height and cane thickness (Chohan *et al*., 2013).

The primary nutrients Nitrogen, Phosphor and Potassium are those that plant need in large quantities and are necessary for all living cells and essential for the formation of chlorophyll (Ali and Hamid, 2012). Cocoly® NPK fertilizer, contribute to the increase in sugarcane yields by providing direct nutritional value and improving the use efficiency of other essential nutrients (El Hag *et al*., 2006). The most important fertilizers used in Kenana Sugar Scheme, are nitrogenous fertilizers Urea and Ammonium Sulphate. and phosphorus fertilizers, Di Ammonium Phosphate (Hamid and Dagash, 2014).

1.1 Objectives of the study:

Main objective is to study the effect of Urea and Cocoly® fertilizers on sugarcane production in the heavy Clay soils of Kenana sugar scheme.

Specific objective is to determine the optimum dose of applied Urea and Cocoly® fertilizers which gives the optimum cane and sugar yield in Kenana Sugar scheme.

II. LITERATURE REVIEW

2.1 Sugarcane Origin and Distribution:

Sugarcane (*Saccharum officinarum* L.) is believed to have originated in New Guinea or the Indo-Myanmar region (Alexander, 1973; Heinz, 2015). It is now cultivated globally, particularly in tropical and subtropical regions (Daniels et al., 1975).

2.2 Soil and Climatic Requirements:

Sugarcane thrives in diverse soils, from sandy loams to heavy clays, but optimal growth occurs in deep, well-aerated soils with adequate organic matter (Savant et al., 1999; Hunsigi, 2012). It requires high solar radiation (C4 photosynthesis), temperatures between 18–33°C, and moderate rainfall (300–2500 mm annually) (Ali, 1998; Marin et al., 2013).

2.3 Sugarcane Propagation and Sugar Yield:

Sugarcane is vegetatively propagated via stalk cuttings, with harvest cycles ranging from 12–24 months (Hamid et al., 2014). Juice extraction yields 9–18% sucrose, contributing to ~70% of global sugar production (Ming et al., 2010). Sudan’s Kenana Sugar Company produces 56% of the country’s sugar (Elzebair et al., 2015).

2.4 Role of NPK Fertilization:

Nitrogen (N), phosphorus (P), and potassium (K) are critical for sugarcane growth and yield (Estrada-Bonilla et al., 2021). Nitrogen enhances vegetative growth, P supports root development and energy metabolism, while K improves sugar translocation and stress resistance (Meyer, 2013; Chohan et al., 2013). Balanced NPK application increases cane height, thickness, and yield (Junejo et al., 2014).

2.5 Cocoly® Fertilizer and Its Components:

Cocoly® is a water-soluble NPK fertilizer enriched with fulvic acids (FAs) and polymeric acid substances (PAS) (Shandong Co, 2013). FAs improve nutrient uptake and stress tolerance (Pettit, 2004), while PAS enhances soil structure and root nutrient retention (Cocoly, 2013). Studies show Cocoly® significantly boosts sugarcane yield when combined with urea (El Hag et al., 2006).

2.6 Fertilizer Uptake and Management:

Sugarcane is a heavy feeder, requiring optimized NPK application to prevent soil depletion (Dotaniya et al., 2016). Excessive nitrogen reduces sucrose content, while deficiencies limit growth (Soomro et al., 2021). Integrated nutrient management, including Cocoly®, improves yield and sugar recovery (Khan et al., 2005).

III. MATERIAL AND METHODS

3.1 The Experimental Site:

An experiment was conducted at the Research and Development Farm of Kenana Sugar Scheme, Sudan, during season - 2021/2022. Kenana is located between White Nile and Blue Nile, at the intersection of longitude 33˚ E, latitude 13˚ N and is 410m above the sea level. Kenana is located about 330km south of Khartoum, and 30km South East of Rabak Town (Elzaki, 2003). The climate is tropical aridic with a summer rainy season of four months, (June to September) with a peak in August. The average annual rainfall is 397 mm. This average fluctuates greatly from year to year. The soil is brown as heavy clay and classified as true vertisols (Ali, 1998). The 60 cm of the soil profile is cracking clay with 40 to 60% clay content (Ali 1986). The dominant clay mineral is montmorillonite (Pecini and Avena, 2013). The soil pH range from7.50 to 8.50 (Jensen, 2010). Above 90% of the upper horizon has an electrical conductivity less than 3 mS/cm^3. The Extractable Sodium Percentage (ESP) is within a range of 510 and 770 ppm (Ali, 1998).

3.2 Experimental Design and Treatment:

The treatments consisted of three Urea fertilizer levels (0, 238, 375 kg/ha) and four Cocoly® fertilizer levels (0, 48, 95, 143 kg/ha). The treatments were arranged in split plot design with four replications, Urea levels were assigned to the main plots and the Cocoly® application to the subplots. The subplot area was 4rows ×8m × 1.50m ($48m^2$).

3.3 Cultural Practices:

3.3.1 Land Preparation:

Land preparation was done according to the standard practice followed at Kenana estate. This consists of deep ploughing at 60 cm (uproot), a second cross deep ploughing at 30 cm, harrowing, leveling and ridging at 1.5 m between ridges.

3.3.2 Fertilizers and Application:

Urea and Cocoly® fertilizers are applied by placement uniformly in the ridges as one dose in the time of planting.

Cocoly® fertilizer is the granular water-soluble fertilizer, produced by Shandong Cocoly Fertilizer Company, China. Cocoly® is a fertilizer with adequate nutrition and has a complete formula, consist of NPK 14:11:10, Fulvic Acid (FA) 0.5% and Polymeric Acid Substance (PAS) 3%.

3.3.3 Variety:

The variety used in the experiment was Co997. Is an Indian promising variety which is agronomical characterized by good germinability, moderate growth rate, shy flowering, considerable resistance to the parasitic weeds, intermediate resistance to the smut disease, trashy with tightly attached leaf sheath and high cane and sugar yields. The variety occupies about 20.0% of the commercial sugarcane fields at Kenana Sugar Scheme.

3.3.4 Planting Date and Methods:

The crop was planted with stem cutting (setts), obtained from 9 months old seed cane, each set, with three buds. The sets were planted by hand in an end to end arrangement and covered with a thin layer of soil. Planting was done on the twenty-fourth of February 2021.

3.3.5 Irrigation:

Irrigation was carried out immediately after planting and subsequently every 10 days throughout the growing season.

3.3.6 Weeds and Insects Control:

Soil was treated by Regent insecticide and Pendimethalin herbicide to control insects and weeds, respectively. The crop received three hand weeding until full canopy was reached and it was treated by 2.4.D twice to control striga infestation.

3.3.7 On Barring:

At the age of three months after planting split-ridging was done.

3.4 Data Collection:

3.4.1 Germination (%):

After sowing, the number of seedlings emerged in each plot were counted.

3.4.2 Cane Height (cm):

Ten stalks were taken randomly from 2-inner rows in each plot for stalk height measurements. Stalk height was measured from the soil surface to the tip of the flag leaf, top-visible-dewlap leaf (TVD) by a measuring tape and the heights were recorded in centimeters.

3.4.3 Cane Girth (mm):

Stalk diameter was measured by (Vernier caliper) at 30 cm above the soil surface from bottom, mid and top portion and averages of three data were used for statistical analysis and the stalk diameters were recorded in millimeters.

3.4.4 Internodes Number:

At harvest, internodes of 25 randomly selected canes from each treatment were counted thereafter, their average was taken.

3.4.5 Stalk Population (1000 plant/ha:

Millable cane stalks in the 2-inner rows of each plot were counted.

3.4.6 Final Yield (ton/ha):

The crop was harvested in March 2022 when the crop is 13-month old. All millable cane in 2-inner rows of each plot were cut manually and arranged in bundles for weighting. The weight of the harvested millable stalks was recorded using portable spring balance and computed to tons per hectare.

3.4.7 Data Statistical Analysis:

Standard analysis of variance of the split plot design using MSTATC statistical computer programs was used to analyze data, Duncan's Multiple Range Test (DMRT) was used to separate significant means (Gomez and Gomez, 1976).

IV. RESULTS AND DISCUSSION

4.1 Effect of Urea and Cocoly® fertilizers and their interaction on cane height (cm):

Effect of Urea fertilizer and Cocoly® fertilizer levels and their interaction on cane height (Table1) showed that, Urea fertilizer had significant effect on cane height. The tallest cane was observed when cane fertilized with 375kg/ha of Urea with a mean cane height of (244.3cm). While, the shortest cane was observed when cane without fertilized of Urea with a mean cane height of (214.4cm). These results agree with (Zeng *et al*., 2020) who obtained that Urea application levels had significant effect on plant height and stalk diameter of sugarcane. Moreover, with the increase of Urea levels, the stalk length and stalk diameter increased.

Table (1) showed that, Cocoly® fertilizer had significant effect on cane height. Moreover, increasing Cocoly® fertilizer levels significantly increased the cane height. The tallest cane was observed when cane fertilized with 143kg/ha of Cocoly® with a mean cane height of (236.8cm). while the shortest cane was observed when cane without fertilized of Cocoly® with a mean cane height of (219.8cm). These result was obtained by (Bokhtiar *et al*., 2002) who found that the cane height and cane thickness increased progressively with application of Cocoly® NPK fertilizer. Besides, Majeedano *et al*., (2003) and (Mahboob *et al*., 2000) who stated that significant maximum cane height was obtained with the balanced Cocoly® NPK application.

The interaction effect of Urea and Cocoly® fertilizer levels on cane height was significant. The tallest cane (252.8cm) was observed when cane fertilized with 375kg/ha of Urea and 143kg/ha of Cocoly®, followed by (252.5cm) was observed when cane fertilized with 375kg/ha of Urea and 95kg/ha of Cocoly®. While, the shortest cane (206.4cm) was observed without Urea and Cocoly® fertilizer application.

TABLE 1
EFFECT OF UREA AND COCOLY® FERTILIZERS AND THEIR INTERACTION ON CANE HEIGHT (cm).

Urea (kg/ha)	Cocoly® (kg/ha)				Mean
	0	48	95	143	
0	206.4 d	214.5 cd	218.6 bcd	218.1 bcd	214.4 B
238	217.6 bcd	228.8 bcd	228.9 bcd	239.5 ab	228.7 AB
375	235.3 abc	236.9 abc	252.5 a	252.8 a	244.3 A
Mean	219.8 B	226.7 AB	233.3 A	236.8 A	
SE ± for Urea		7.87**			
SE ± for Cocoly®		4.17**			
SE ± for Interaction		7.22**			
CV(%)		6.3			

Means followed by the same letter (s) are not significantly different according to Duncan's Multiple Range Test (DMRT).

4.2 Effect of Urea and Cocoly® fertilizers and their interaction on internodes number:

Table (2) shows that the effect of Urea and Cocoly® fertilizer levels and their interaction on internodes number of sugarcane. The results showed that Urea fertilizer had a significant effect on internodes number. The highest internodes number were obtained when cane fertilized 375kg/ha of Urea with a mean of (25) internodes. While the lowest internodes number were obtained without Urea fertilizer with a mean of (21) internodes. These results were in line with the finding of (Ali *et al*., 2000) who stated that increasing Urea fertilizer significantly increased internodes cane number. On the other hand, Cocoly® fertilizer levels had a non-significant effect on internodes number.

The interaction between Urea and Cocoly® fertilizer levels had a significant effect on internodes number. The high internodes number (25) were obtained when cane fertilized with 375kg/ha of Urea with 143, 95 and 48kg/ha of Cocoly® was used respectively. The higher internodes number may be attributed to, genetically controlled characters.

TABLE 1
EFFECT OF UREA AND COCOLY® FERTILIZERS AND THEIR INTERACTION ON INTERNODES NUMBER.

Urea (kg/ha)	Cocoly® (kg/ha)				Mean
	0	48	95	143	
0	21 b	21 b	21 b	23 ab	21 B
238	21 b	23 ab	23 ab	24 ab	23 B
375	24 ab	25 a	25 a	25a	25 A
Mean	22	23	23	24	
SE ± for Urea		0.39**			
SE ± for Cocoly®		0.50			
SE ± for Interaction		0.89**			
CV(%)		8.2			

Means followed by the same letter (s) are not significantly different according to Duncan's Multiple Range Test (DMRT).

4.3 Effect of Urea and Cocoly® fertilizers and their interaction on cane girth (mm):

The effect of Urea and Cocoly® fertilizer levels and their interaction on cane girth is shown in (Table 3). The results showed that, Urea fertilizer had a significant effect on mean cane girth. The largest cane girth was observed when cane fertilized with 375kg/ha of Urea with a mean cane girth (22cm). while the smallest cane girth was observed when cane without fertilization with Urea with a mean cane girth (20.8cm). These results agreed with the finding of (Zeng *et al.,* 2020) who reported that Urea application levels had significant effect on stalk diameter and plant height of sugarcane. In addition to, Urea fertilizer improved the stalk diameter, tillering rate, plant height, stalk weight, millable stalks/ha and cane yield.

Cocoly® fertilizer levels had no significant effect on mean cane girth. These results was contrary to that obtained by (Bangar *et al*., 1994), (Sharma and Gupta, 1991), (Mahboob *et al*., 2000) and (Shafshak *et al*., 2001) who reported that the maximum cane girth obtained when applied higher doses of Cocoly® NPK fertilizer. Moreover, Bokhtiar *et al*., (2002) found that cane thickness and cane height increased progressively with the application of Cocoly® NPK fertilizer. Besides, Majeedano *et al*., (2003) stated that significantly maximum cane thickness and cane height was obtained with the balanced Cocoly® NPK application.

The interaction effect of Urea and Cocoly® fertilizer levels on cane girth was significant. The highest cane girth 23.65 was obtained when cane fertilized with 143kg/ha of Cocoly® and 238kg/ha of Urea.

TABLE 1
EFFECT OF UREA AND COCOLY® FERTILIZERS AND THEIR INTERACTION ON CANE GIRTH (mm).

Urea (kg/ha)	Cocoly® (kg/ha)				Mean
	0	48	95	143	
0	21.27 ab	19.83 b	20.77 ab	21.40 ab	20.82 B
238	22.02 ab	20.65 ab	21.02 ab	23.65 a	21.84 A
375	22.25 ab	22.10 ab	21.48 ab	22.00 ab	21.96 A
Mean	21.85	20.86	21.09	22.35	
SE ± for Urea		0.23**			
SE ± for Cocoly®		0.55**			
SE ± for Interaction		0.95			
CV (%)		8.9			

Means followed by the same letter (s) are not significantly different according to Duncan's Multiple Range Test (DMRT).

4.4 Effect of Urea and Cocoly® fertilizers and their interaction on stalk population (1000 plant/ha):

Table (4) shows that the effect of Urea and Cocoly® fertilizer levels and their interaction on cane population. The results showed that application of Urea fertilizer has a non-significant effect on stalk population. These results are contrary to that obtained by (Borden 1945) who reported that higher amounts of Urea produced dense stalk population. In addition to that, (Afzal *et al*., 2003) and (Sinha *et al*., 2005) reported that increasing the dose of Urea increased number of millable cane per unit area.

Cocoly® fertilizer levels had significant effect on stalk population. Thus, increasing Cocoly® fertilizer increased stalk population. The higher stalk population with a mean of (145) was obtained when sugarcane fertilized with 95kg/ha of Cocoly®. While lower stalk population with a mean of (135) was obtained when sugarcane without treated by Cocoly®. These results were supported by finding of (Asif *et al*., 2002). Who reported that cane millable stalks, increased progressively with increased application of Cocoly® NPK fertilizer.

The interaction effect of Urea and Cocoly® fertilizer levels on plant population was significant. The highest stalk number (154) was obtained when 375kg/ha of Urea and 143kg/ha of Cocoly® were applied.

TABLE 1
EFFECT OF UREA AND COCOLY® FERTILIZERS AND THEIR INTERACTION ON STALK POPULATION (1000 plant/ha)

Urea (kg/ha)	Cocoly® (kg/ha)				Mean
	0	48	95	143	
0	133 b	134 b	141 ab	138 b	136
238	137 b	148 ab	146 ab	138 ab	142
375	136 b	145 ab	148 ab	154 a	146
Mean	135 B	142 AB	145 A	143 AB	
SE ± for Urea		2006.1			
SE ± for Cocoly®		1186.3**			
SE ± for Interaction		2054.8**			
CV(%)		6.9			

Means followed by the same letter (s) are not significantly different according to Duncan's Multiple Range Test (DMRT).

4.5 Effect of Urea and Cocoly® fertilizers and their interaction on stalk weight (kg):

The effect of Urea an Cocoly® fertilizer levels and their interaction on stalk weight is shown in (Table 5). The results showed that, Urea fertilizer had a non-significant effect on mean stalk weight. These results disagreed with the results of (Zeng *et al*., 2020) who reported that Urea fertilizer had significant effect on the stalk weight, stalk diameter, tillering rate, plant height, millable stalks/ha and cane yield.

Cocoly® fertilizer had a significant effect on stalk weight. The highest stalk weight was obtained when sugarcane fertilized with 143kg/ha of Cocoly® with a mean of 1.23kg. While the lowest stalk weight was obtained when Cocoly® fertilizer untreated with a mean of 1.08kg, followed by 1.08kg was obtained when cane fertilized with 48kg/ha of Cocoly®. These results were in line with the findings of (Faqir and Shahid 2000) who obtained that maximum stalk weight, number of millable cane per meter square, and cane yield at the rate of Cocoly® NPK fertilizer 150 kg/ha.

The interaction between Urea and Cocoly® fertilizer levels had a significant effect on mean stalk weight (kg). The highest value of stalk weight (1.3kg) was obtained when sugarcane fertilized with 375kg/ha of Urea and 143kg/ha of Cocoly®. While the lowest value of stalk weight (1.0kg) was obtained when sugarcane fertilized with 238kg/ha of Urea and 48kg/ha of Cocoly®.

TABLE 1
EFFECT OF UREA AND COCOLY® FERTILIZERS AND THEIR INTERACTION ON STALK WEIGHT (kg).

Urea (kg/ha)	Cocoly® (kg/ha)				Mean
	0	48	95	143	
0	1.100 ab	1.175 ab	1.100 ab	1.175 ab	1.138
238	1.050 ab	1.000 b	1.050 ab	1.200 ab	1.075
375	1.100 ab	1.075 ab	1.225 ab	1.300 a	1.175
Mean	1.083 B	1.083 B	1.125 AB	1.225 A	
SE ± for Urea		0.15			
SE ± for Cocoly®		0.04**			
SE ± for Interaction		0.08**			
CV(%)		13.5			

Means followed by the same letter (s) are not significantly different according to Duncan's Multiple Range Test (DMRT).

4.6 Effect of Urea and Cocoly® fertilizers and their interaction on cane yield (ton/ha):

Urea fertilizer had a significant effect on cane yield as shown in (Table 6). These results agreed with (Ibrahim, 1979) who reported that Urea application generally increased the yields of both cane and sugar. Furthermore, increase in cane tonnage due to increase in Urea fertilizer application has been reported by (Samuels *et al*., 1952), (Parashar *et al*., 1980), (Silva *et al.*, 2019) and (Zeng *et al.*, 2020). Similarly, Yang *et al*., (2019) reported that larger Urea supplies increased yield by increasing cane weight and height.

Cocoly® fertilizer levels had a significant effect on cane yield. The result is indicated that, cane yield increased with increasing Cocoly® fertilizer levels. These results agreed with (Faqir and Shahid, 2000) who reported that cane yield was significantly increased with Cocoly® fertilizer application. Khan *et al*., (2005) reported that sugarcane yield increased with the increase in balanced nutrients levels. Yadava, (1993) stated that being a long duration crop an adequate and balanced supply of all these nutrients is required for obtaining sustainable crop yield. Asif *et al*., (2002), (Nasir *et al*., 1994) and (Ayoub *et al*., 1999) reported that Cocoly® NPK application was important for maximum cane yield. Chaudhry and Chattha, (2000) reported that, maximum cane yield was obtained when using Cocoly® NPK fertilizer.

The significant positive relationship between cane yield and different Cocoly® levels were observed by (Bokhtiar *et al*., 2002) and (Gurmani and Khan, 2003).

The cane yield parameters i.e. cane height, number of tillers, millable cane stalks, yield of cane and sugar increased significantly with application of Cocoly® NPK levels as reported by (Asif *et al*., 2002).

Interaction between Urea and Cocoly® fertilizer levels had a significant effect on cane yield. The highest cane yield (199.9 t/ha) was obtained when sugarcane fertilized with 375kg/ha of Urea and 143kg/ha of Cocoly®. While the lowest yield (138.3 t/ha) was obtained without Urea and Cocoly® fertilizers application.

TABLE 1
EFFECT OF UREA AND COCOLY® FERTILIZERS AND THEIR INTERACTION ON CANE YIELD (ton/ha).

Urea (kg/ha)	Cocoly® (kg/ha)				Mean
	0	48	95	143	
0	138.3 c	147.1 bc	149.5 bc	152.0 bc	146.7 B
238	140.7 c	149.2 bc	151.2 bc	164.1 bc	151.3 B
375	152.2 bc	159.2 bc	178.7 ab	199.9 a	172.5 A
Mean	143.8 B	151.8 B	159.8 B	172.0 A	
SE ± for Urea		6.00**			
SE ± for Cocoly®		2.30**			
SE ± for Interaction		4.00**			
CV(%)		12.1			

Means followed by the same letter (s) are not significantly different according to Duncan's Multiple Range Test (DMRT).

V. CONCLUSIONS AND RECOMMENDATION

5.1 Conclusion

- Increasing Urea fertilizer levels significantly increased cane height, cane girth, cane internodes and cane yield.
- Increasing Cocoly® fertilizer levels significantly increased plant height, stalk population, stalk weight and cane yield.
- The highest cane yield (199.9 t/ha) was obtained when 375kg/ha of Urea and 143kg/ha of Cocoly® were applied.

5.2 Recommendation:

Based on the results of this study it could be recommended that to obtain high cane yield of Sugarcane (variety Co997), the crop should be fertilized by Urea at the rate of 375kg/ha and Cocoly® at the rate of 143 kg/ha.

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Quality Assessment of Irrigation Waters used in Agricultural Fields of Mersin Mezitli District and Irrigation-Induced Soil Salinity Assessments

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***Abstract*—** *This study was conducted to determine the irrigation water quality of water sources used in agricultural fields of the Mezitli district of Mersin province and the salinity level of agricultural lands irrigated with these waters. Water samples were taken from water resources used to irrigate lands of the research area once a month for four months (July, August, September and October) during the irrigation season. The pH values of irrigation water samples taken in July, August, September and October varied between 7.05 - 8.26 and the EC values varied between 292 - 1103 µmhos/cm. According to the US Salinity Laboratory Classification System, present water samples were classified as C_2S_1 and C_3S_1, indicating moderate to high salinity. Boron concentrations of all samples were below the threshold boron level of 0.67 ppm.*

During a period of intensive irrigation in the areas where the research was conducted (August), soil samples were taken from a depth of 30 cm to 90 cm of five plots. Soil textures were identified as clay, loamy and clay-loam. Soil pH values varied between 7.38 - 7.95 and soil EC values varied between 1985 - 3180 µmhos/cm. It was determined that the soil salinity was below the threshold value of 4000 µmhos/cm. No significant differences in quality or quantity were observed in the water samples throughout the irrigation season (July - October) and the soil samples did not pose any risks in terms of salinity and boron toxicity under the current conditions.

***Keywords*— *Irrigation, irrigation water quality, saline irrigation water, sodium content, soil salinity*.**

I. INTRODUCTION

Irrigation water salinity, measured as electrical conductivity (EC), is the most effective water quality indicator for crop productivity. Crops cannot compete with ions in the soil solution for water in case of high EC levels of irrigation water, then salinity-induced yield losses are encountered. The higher the EC, the less water is available to plants, even though the soil appears to be wet **[1].**

Soil salinity and alkalinity are common processes that characterize arid areas in particular. These processes can be attributed to natural conditions or anthropogenic activities. Natural conditions include climate, lithology, topography and pedology, while human-induced activities are mostly related to agricultural land use and in particular to irrigation. Over time, the extent of saline, alkaline and saline-alkaline agricultural lands has increased, such a case then resulted in accelerated land degradation and desertification, reduced agricultural productivity and ultimately jeopardized environmental health and food safety. Mapping and monitoring saline soils is an important management tool aimed at determining the extent and severity of salinization processes. Recent advances in remote sensing methods have increased the effectiveness of mapping and monitoring processes of saline soils. The knowledge and experience regarding the prevention, reduction and improvement of soil salinity and alkalinity have increased significantly over time **[2].**

[3] indicated that in modern irrigation systems, quality of irrigation water is as important as the amount, timing and method of irrigation. When sufficient and good-quality water is not available, water that is unsuitable for irrigation is commonly used. Such a case then increases soil salinity levels. Therefore, to evaluate the water quality in the ponds used for irrigation in Hakkari province, water samples were taken from 10 irrigation ponds in June, July, August and September. The water samples were analyzed for electrical conductivity (EC), pH, anions and cations (Ca^{2+}, Mg^{2+}, K^+, Na^+, SO_4^{2-}, NO_3^{2-}, CO_3^{2-}, HCO_3^-, and Cl^-). Additionally, using the resultant data, Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC) and Sodium Percentage (% Na) values were calculated. It was observed that the pH, EC, SAR, RSC and % Na values of irrigation pond waters did not exceed the limit values, but the Mg^{+2} and K^+ values of the pond water in the Kanatlı area of Akçalı Village and the K^+ value of the pond water in the Şişer area of Kırıkdağ Village exceeded the threshold values.

The SAR value of irrigation water is the primary parameter designating water quality class. Therefore, results obtained from studies conducted with sodium salt without considering the SAR value represent sodium damage rather than salt damage. To determine the level of irrigation water salinity that maize lants can tolerate, germination and pot experiments were conducted with irrigation waters of different salt concentrations by setting the SAR value below 1. Germination experiments revealed that root lengths, seedling dry weights and germination rates decreased with increasing irrigation water salinity levels. Root lengths began to be negatively affected at an irrigation water salinity level of 3 dS m^{-1} ECi, while seedling dry weights and germination rates began to be affected at a level of 5 dS m^{-1} ECi. In pot experiments, plant heights and plant dry weights decreased with increasing irrigation water salinity levels and were negatively affected at salinity level of 8 dS m^{-1} ECi **[4].**

It was determined in a study on the effect of irrigation water of different qualities on alfalfa that growth slowed down in alfalfa irrigated with saline water and harvest yield and quality decreased. Contrarily, when leaching (washing) was performed and salts were removed from the environment, plant growth returned to normal levels. Accordingly, it was determined that for high alfalfa yields, irrigation water salinity should be below 1.5 dSm^{-1} **[5].**

Soil salinity and alkalinity occur in arid and semi-arid regions of the world where irrigated agriculture is practiced. Low rainfall, poor-quality irrigation water and high evaporation rates contribute to salinity and alkalinity issues in such regions. These issues also impair the structural properties of the soil (**[6].**; **[7]**).

[8] conducted a study with the irrigation water resources of Ankara Haymana Soğulca Village irrigation cooperative and stated that the irrigation water samples were C_3 (excessively saline water) and could not be used in areas with limited drainage. Despite the presence of salinity issues in the irrigation water resources of the study area, it was noted that no salinity problems arose in the agricultural lands where these waters were used. It was also emphasized that although no salinity issues were observed in the agricultural lands of the region, it is essential to develop both closed and open drainage systems to prevent future salinity problems in these agricultural lands.

[9] examined the possible effects of using drainage water for irrigation on the water and salt balance of the soils in the Harran Plain. It was determined that open drainage canal water in the plain contained less salt than sub-surface drainage water and that salt content decreased toward the end of the season. In areas with drainage systems, the water table level generally remains at a depth of 140–160 cm during the irrigation season. Under these conditions, the SaltMod computer model predicts that root zone salinity will decrease from 7.0 to 3.0 dSm^{-1} within 3 years and to 1.5 dSm^{-1} within 10 years. Additionally, irrigation with water having an EC of 1.5 dSm^{-1} will cause a decrease in soil salinity, while irrigation with water with EC=2.5-3.0 dS m^{-1} and above will cause an increase in soil salinity.

[10] conducted a study in the Biga Plain of Çanakkale province and analyzed water samples taken from 20 wells for electrical conductivity (EC), pH, potassium (K), calcium (Ca), magnesium (Mg), Sodium (Na), Carbonate (CO3), Bicarbonate (HCO3), Chloride (Cl), Sulfate (SO4), Nitrate (NO3) and Boron (B) parameters. Considering the Water Pollution Control Regulation (SKKY) Classification System, water samples of 11 wells were classified as second class and the others as first class. The study found that apart from nitrate pollution in groundwater, no significant problems had yet emerged in the study area.

[11] conducted a study in the Isparta Plain to examine the quality of irrigation water in water samples taken from 21 groundwater wells and found that the water quality in some of the wells was classified as C_3S_1 (highly saline - low alkaline), while the water quality in other wells was classified as C_2S_1 (moderately saline - low alkaline).

[12] conducted a study to determine the impact of domestic and industrial waste waters on water quality of Nilüfer River. Water samples were taken from the discharge points of five wastewater treatment plants discharging into the Nilüfer River and from the streams into which these plants discharge during four different periods between August 2013 – May 2014. It was determined that the water quality parameters of Nilüfer River and some of the wastewater treatment plants discharging into the Nilüfer River varied depending on the period. Based on the classification made considering EC and SAR, water samples were classified into the C_2S_1 - C_4S_4 classes. It was also determined that the wastewater discharged from treatment plants had a negative impact on the Nilüfer River, particularly in terms of pH, EC, ammonium, phosphorus, sulfate, boron and chlorine values.

It was found in a study conducted by **[13]** in the Sultanhisar district of Aydın Province that the quality of water used for irrigation varied between C_2S_1 and C_3S_1 classes over time. It was also determined that the canal water used affected fruit quality and boron concentrations were higher than that of the control group plants.

[14] selected a total of 17 sampling sites along the Awash River and its tributaries and conducted sampling four times a year in different seasons to assess the water quality of the Awash River and its tributaries. Researchers assessed the overall water quality and suitability for irrigation using numerous water quality parameters such as pH, EC, SAR, RSC, Na^+, K^+, Ca^{++} , Mg^{++}, CO_3^{2-}, HCO_3^- and Cl^-. It was determined that all quality parameters in Lake Beseka exceeded the maximum permissible limits for irrigation, the physicochemical characteristics of the Awash River showed variations in different water quality parameters across different sites. Only the pH and SAR of Beseka Lake and Meteka hot spring water exceeded the permitted limit and the EC values in Mojo, Wonji, Beseka, Melkasedi, Werer, Ambash, Meteka and Meteka hot springs showed medium-high salinity values, while the RSC was very high. It was recommended that wastewater treatment plants should be constructed for industries to improve water quality.

II. MATERIAL AND METHOD

Mezitli district on the Mediterranean coast is highly rich in natural heritage. It has a surface area of 515.79 km^2. Its average elevation above sea level is between 3 - 5 meters. Three-quarters of Mezitli consists of mountains, plateaus and undulating terrains. The coastal strip between the mountains and the sea narrows as it extends westward. The Taurus Mountains, with their geographical position, act as a barrier against northern winds, contributing to the typical Mediterranean climate prevailing in the region.

Mezitli is among the districts with the highest sunshine duration in Turkiye. About 300 days of the year are sunny. The average daily sunshine duration is 7.4 hours, varying between 8–10 hours during the summer months. The average relative humidity is 72%, remaining relatively consistent throughout the year. The average relative humidity varies between 65–75% depending on the month. The annual average temperature is 18.4 °C. The average temperature in summer is 25–33 °C, the average temperature in winter is 9–15 °C and the average sea water temperature is 20 °C. The sea water temperature, which rises to 28 °C in summer, remains at this temperature for a long time, making it the most important factor in extending the tourism season in the district.

The average annual precipitation is 618.6 mm. The highest precipitation is received in December and the lowest in August. There are no plains in the district, but there are mountains in the north named Gemrik, Garkın, Kalegediği, Gelin Kayası, Eyüp Kayası, Hazmur, Karagedik, Gicik Kayası, Hürükızları Kepez, Manıt, Saladağ, Kuşkayası, Durnaz, Peynir and Koca Ellez. These mountains have an average elevation of 1,400 - 1,800 m. The Kandak, Tece and Mezitli rivers flow through the district center.

The maquis, which is seen between 500 and 600 meters above sea level, is a typical plant community of the Mediterranean region that remains green throughout the year. Laurel, wild olive, caper, myrtle, oleander, thorny wood apple, blackberry and rosehip grow naturally in this belt. Forests begin after the maquis. Oak trees grow at 100–1,000 meters, red pine at 100–1,200 meters, black pine at 1,500 meters and cedar and juniper at 2,000 meters. Above 2,500 meters, shrubs and grasslands are found. These are the living areas of the nomads (Yörük) **[15].**

The location of the research site is presented in Figure 1.

FIGURE 1. Research site

Twenty sampling points were selected from surface irrigation water resources used in irrigated agricultural areas of the Mezitli district. Water samples were taken regularly every month for four months during the irrigation season (July-October). The pH and EC readings were made each month and irrigation water samples taken in August were subjected to water-soluble cations (Ca, Mg, Na, K), anions (CO_3, HCO_3, Cl and SO_4) and boron analyses. Measured values were used to calculate sodium percentage (%Na), sodium absorption ratio (SAR), residual sodium carbonate (RSC) and to identify irrigation water quality class.

During a period of intensive irrigation in the areas where the research was conducted (August), soil samples were taken from a depth of 30 cm to 90 cm of five plots. Soil samples were subjected to physical (saturation, field capacity, permanent wilting point, available water, bulk density, texture) and chemical (pH, EC, cations, anions, cation exchange capacity, exchangeable cations, exchangeable sodium percentage, lime, boron) analyses.

III. RESULTS AND DISCUSSION

Water samples were taken from water resources used to irrigate lands of the research area once a month for four months (July, August, September and October) during the irrigation season.

The pH and EC values of irrigation water samples taken in July, September and October are provided in Table 1. In July, pH values of irrigation water samples varied between 7.07 - 8.11 and EC values between 343 - 1045 µmhos/cm. In September, pH values varied between 7.14 - 8.15 and EC values between 308 - 1103 µmhos/cm. In October, pH values of irrigation water samples varied between 7.05 - 8.02 and EC values between 344 - 1056 µmhos/cm.

In July, the highest salinity values were seen in samples 16 and 17: samples 15, 16, 17 and 20 had salinity levels above the threshold salinity level of 750 µmhos/cm, while the other samples were below the safe limit (750 µmhos/cm), making them more suitable for irrigation purposes. In September, the highest salinity values were seen in samples 14, 15, 16 and 17, which exceeded the threshold value of 750 µmhos/cm, while the other samples were below the safe limit value (750 µmhos/cm), making them more suitable for irrigation purposes. In October, the highest salinity levels were seen in samples 14, 15, 16 and 17 with a salinity value of above the threshold salinity value of 750 µmhos/cm, while the other samples were below the safe limit value (750 µmhos/cm), again making them more suitable for irrigation. The EC values of the irrigation water samples taken from the region, categorized by month (July, September, October) and sample number, are presented in Figures 2, 3 and 4.

The chemical analysis results of irrigation water samples for August are provided in Table 2. The pH values of irrigation water samples varied between 7.16 - 8.26, the EC values between 292 - 1101 µmhos/cm and boron concentrations were below the optimal limit of 0.67 ppm in all samples. In terms of water-soluble anions and cations, it can be stated that Ca was dominant among cations and HCO_3 among anions. Sodium adsorption ratios (SAR) ranged from 0.04 to 3.14, % Na values ranged from

1.51 to 47.99 and residual sodium carbonate (RSC) values ranged from 1.72 to 1.90 (in samples 16 and 17). According to US Salinity Lab Classification System, water samples taken in August were classified as C_2S_1 and C_3S_1.

The EC values of the August irrigation water samples based on sample numbers are shown in Figure 5. The highest salinity values were seen in samples 14, 15, 16 and 17, which were above the threshold salinity value of 750 µmhos/cm, while the salinity values of the other samples were below the safe limit value (750 µmhos/cm), making them more suitable for use in irrigating fields.

In terms of boron concentrations given in Table 2, it was observed that boron concentrations of the irrigation water samples were all below the safe boron value of 0.7 ppm, indicating that there would be no boron-related problems with irrigation in August.

TABLE 1
THE pH AND EC VALUES OF IRRIGATION WATER SAMPLES TAKEN IN JULY, SEPTEMBER AND OCTOBER

Sample No	July		September		October	
	pH	EC x 10^6 µmhos/cm 25ºC	pH	EC x 10^6 µmhos/cm 25ºC	pH	EC x 10^6 µmhos/cm 25ºC
1	8,11	549	7,93	551	7,86	548
2	7,72	553	7,88	547	7,98	556
3	7,60	452	8,11	525	8,02	498
4	7,65	435	8,15	516	8,01	502
5	7,40	452	8,08	519	7,88	503
6	7,09	585	7,20	554	7,15	576
7	7,08	582	7,23	570	7,05	565
8	7,60	351	7,82	311	7,88	346
9	7,56	351	7,90	308	7,75	344
10	7,30	343	7,44	353	7,50	349
11	7,31	349	7,50	351	7,66	359
12	7,90	715	7,48	724	7,60	710
13	7,80	717	7,39	730	7,48	720
14	7,11	724	7,15	1015	7,05	935
15	7,09	752	7,14	1040	7,11	1005
16	7,39	1045	7,56	1103	7,45	1018
17	7,31	1045	7,60	1094	7,55	1056
18	7,31	562	7,30	424	7,85	496
19	7,68	569	7,46	416	7,68	511
20	7,07	752	7,22	624	7,26	703

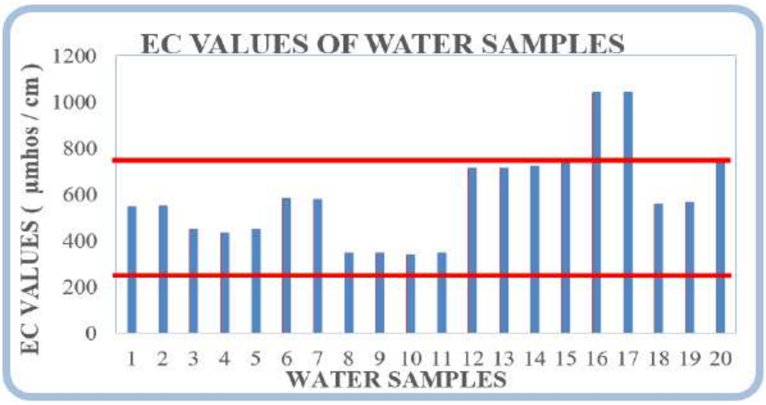

FIGURE 2: EC values of irrigation water samples taken in July

TABLE 2
CHEMICAL ANALYSIS RESULTS OF IRRIGATION WATER SAMPLES TAKEN IN AUGUST

Sample No	pH	ECx10^6 µmos/cm 25 ºC	WATER - SOLUBLE										RSC	SAR	%Na	Irrigation Water Class	Boron (mg/L)
			Cations (me/l)					Anions (me/l)									
			Na^+	K^+	Ca^{+2}	Mg^{+2}	Total	CO_3^{-2}	HCO_3^-	Cl^-	SO_4^{-2}	Total					
1	7,97	546	0,56	0,04	0,98	3,11	4,69	0,00	1,40	1,74	1,55	4,69	-	0,39	11,97	C_2S_1	<0,67
2	8,04	546	0,56	0,04	0,99	3,21	4,80	0,00	1,40	1,98	1,43	4,81	-	0,39	11,61	C_2S_1	<0,67
3	8,19	534	0,65	0,11	3,36	2,12	6,24	0,00	2,73	1,62	1,88	6,23	-	0,39	10,36	C_2S_1	<0,67
4	8,21	534	0,65	0,11	3,40	2,10	6,26	0,00	3,05	1,74	1,48	6,27	-	0,39	10,43	C_2S_1	<0,67
5	8,26	535	0,65	0,11	3,47	2,12	6,35	0,00	2,90	1,63	1,82	6,35	-	0,39	10,24	C_2S_1	<0,67
6	7,20	560	0,26	0,01	5,53	0,98	6,78	0,00	3,26	1,62	1,90	6,78	-	0,14	3,84	C_2S_1	<0,67
7	7,27	588	0,26	0,01	5,61	1,00	6,88	0,00	3,44	1,53	1,91	6,88	-	0,14	3,75	C_2S_1	<0,67
8	7,85	292	0,06	0,00	3,22	0,29	3,57	0,00	0,45	1,52	1,60	3,57	-	0,04	1,56	C_2S_1	<0,67
9	7,93	293	0,07	0,00	3,20	0,32	3,59	0,00	0,27	1,48	1,85	3,60	-	0,05	1,94	C_2S_1	<0,67
10	7,55	346	0,08	0,01	3,66	0,51	4,26	0,00	0,79	1,58	1,88	4,25	-	0,05	1,81	C_2S_1	<0,67
11	7,49	353	0,07	0,01	3,76	0,49	4,33	0,00	1,08	1,52	1,72	4,32	-	0,05	1,51	C_2S_1	<0,67
12	7,38	709	0,69	0,07	3,47	4,04	8,27	0,00	4,80	1,67	1,80	8,27	-	0,36	8,36	C_2S_1	<0,67
13	7,37	706	0,69	0,07	3,50	4,16	8,42	0,00	4,87	1,62	1,93	8,42	-	0,35	8,22	C_2S_1	<0,67
14	7,21	1082	1,64	0,05	5,24	5,43	12,36	0,00	8,80	1,84	1,73	12,37	-	0,71	13,30	C_3S_1	<0,67
15	7,16	1101	1,65	0,05	5,13	5,27	12,10	0,00	8,77	1,87	1,46	12,10	-	0,72	13,64	C_3S_1	<0,67
16	7,51	1082	5,12	0,08	1,96	4,12	11,28	0,00	7,80	1,81	1,67	11,28	1,72	2,94	45,39	C_3S_1	<0,67
17	7,55	1097	5,26	0,08	1,47	4,14	10,95	0,00	7,51	1,69	1,75	10,95	1,90	3,14	47,99	C_3S_1	<0,67
18	7,94	362	0,12	0,01	3,30	1,06	4,49	0,00	1,30	1,98	1,21	4,49	-	0,08	2,63	C_2S_1	<0,67
19	7,73	355	0,13	0,01	3,40	1,07	4,61	0,00	1,25	1,67	1,68	4,60	-	0,09	2,78	C_2S_1	<0,67
20	7,30	599	0,47	0,01	4,49	2,22	7,19	0,00	3,73	1,91	1,56	7,20	-	0,26	6,58	C_2S_1	<0,67

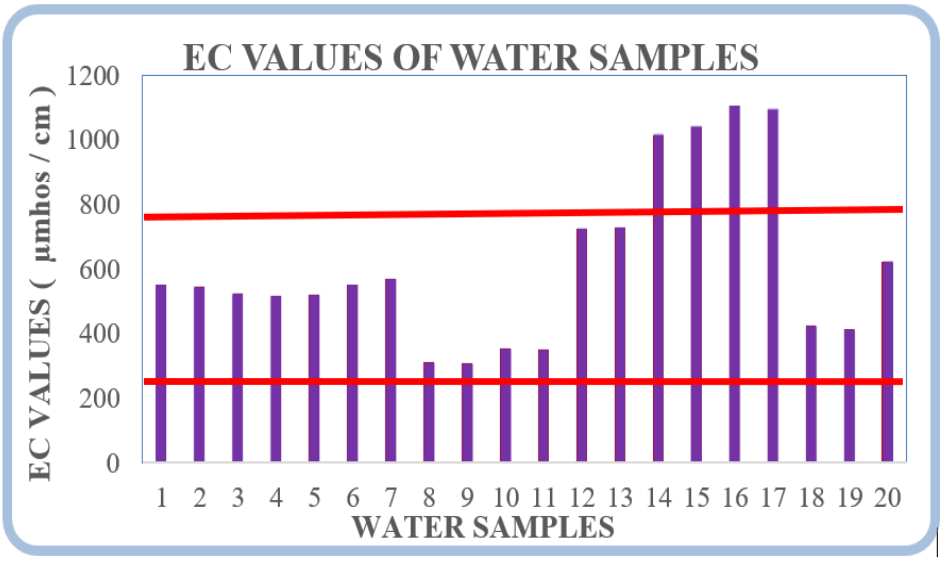

FIGURE 3: EC values of irrigation water samples taken in September

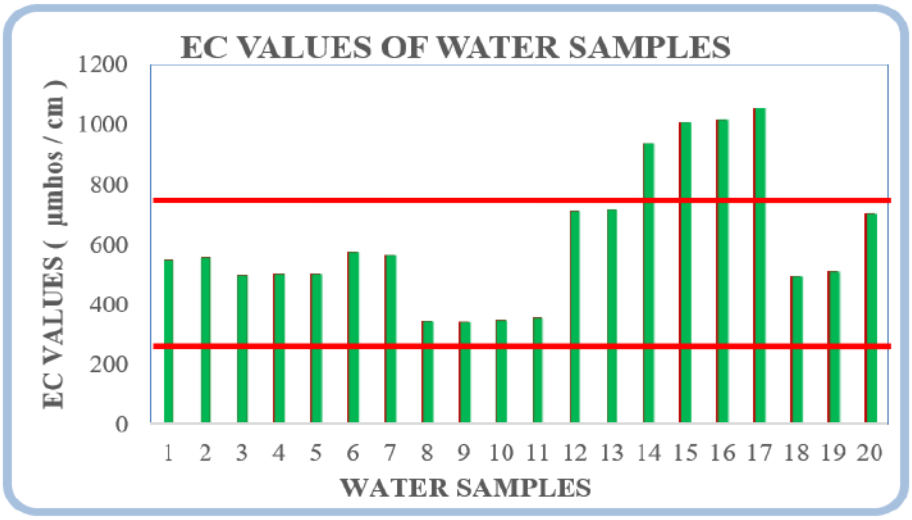

FIGURE 4: EC values of irrigation water samples taken in October

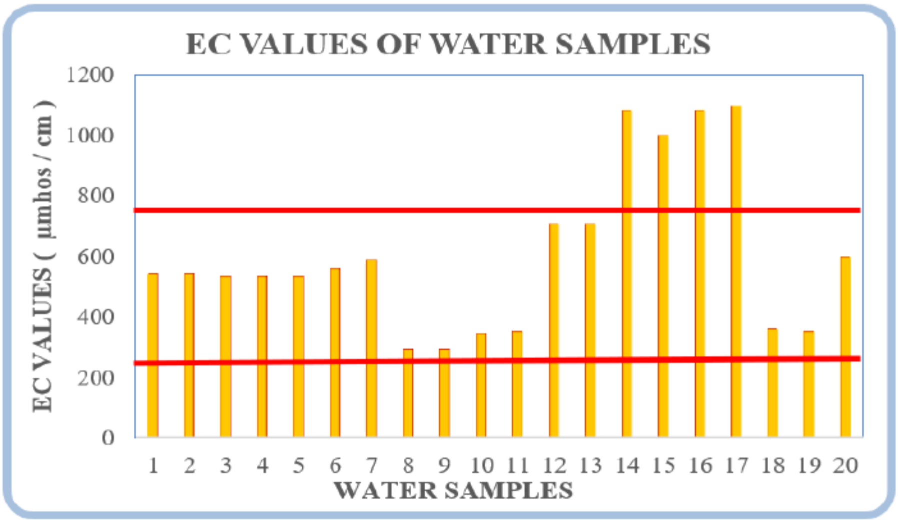

FIGURE 5: EC values of irrigation water samples taken in August

Physical and chemical analysis results of the soil samples taken from the research area are provided in Table 3 and Table 4. Soil textures were identified as loamy (L), clay-loam (CL) and clay (C), with saturation values ranging from 50.45% to

114.35% (which can exceed 100% depending on the clay type), field capacity values of between 22.50 - 36.40%, permanent wilting points of between 13.98 - 24.46% and bulk density values of between 1.28 - 1.39 g/cm³ (Table 3). Soil pH values varied between 7.38 - 7.95 and salinity values varied between 1985 - 3180 µmhos/cm. Soil samples all had salinity levels of below the threshold salinity value of 4000 µmhos/cm (Table 4).

While HCO_3^- was the dominant water-soluble anion, Ca^{+2} was the dominant cation. The boron concentrations of all samples were found to be below 4 ppm, ranging from 0.25 to 0.39 ppm. Cation exchange capacities (CEC) ranged from 8.95 to 13.16 me/100 g, while exchangeable sodium percentages (ESP) ranged from 6.59 to 14.86%, both below the accepted ESP threshold of 15%. The lime values were found to vary between 7.78% and 49.23%.

The relationships between soil EC and depth is shown in Figure 6 and the relationships between soil ESP and depth is shown in Figure 7. The relationships between EC and depth of soil samples showed that the average EC values at depths of 0-30, 30-60, and 60-90 were between 2000 and 3000 µmhos/cm, with no significant differences between the depth segments. The high EC values observed in some irrigation water samples indicate that the soil is not becoming saline, but rather that salt is leached from the soil. Figure 7 shows that there is no change in ESP values with the depth and ESP values were all below the accepted limit value of 15%.

TABLE 3
SOIL PHYSICAL ANALYSIS RESULTS

Soil Sampling		Saturation (%)	Field Capacity (Volume %)	Permanent Wilting Point (Volume %)	Available Water (%)	Bulk Density (g/cm^{-3})	Soil Particles			Soil Texture
Plot No	Depth (cm)						Sand %	Clay %	Silt %	
1	0-30	50,60	22,74	13,98	8,76	1,33	49,01	22,43	28,56	L
	30-60	50,75	22,80	17,70	5,10	1,34	52,10	22,43	25,00	L
	60-90	50,45	22,50	21,35	1,15	1,36	49,00	23,50	20,50	L
2	0-30	93,50	34,96	24,24	10,72	1,28	39,71	44,86	15,42	C
	30-60	93,70	35,23	24,35	10,88	1,32	39,70	40,30	15,80	C
	60-90	93,55	34,75	24,46	10,29	1,38	42,50	40,20	15,40	C
3	0-30	68,20	27,49	18,13	9,36	1,29	37,93	33,01	29,06	CL
	30-60	66,30	27,12	18,54	8,58	1,35	39,80	33,00	25,20	CL
	60-90	66,15	26,96	18,35	8,61	1,39	37,93	28,50	31,30	CL
4	0-30	75,90	34,56	23,81	10,75	1,29	39,79	42,22	18,00	C
	30-60	76,10	34,88	23,96	10,92	1,32	40,56	46,50	14,50	C
	60-90	73,60	33,96	24,18	9,78	1,36	40,60	42,22	16,20	C
5	0-30	112,20	35,92	23,03	12,89	1,28	31,20	45,08	17,35	C
	30-60	111,40	35,76	23,55	12,21	1,30	33,60	42,50	17,50	C
	60-90	114,35	36,40	23,50	12,90	1,33	37,75	42,50	14,30	C

TABLE 4
SOIL CHEMICAL ANALYSIS RESULTS

Soil Sampling		pH	EC x 10^6 µmos/cm 25 ºC	Water - Soluble										CEC (me/100 g)	Exchangeable Cations			ESP (%)	Lime (%)	Boron (ppm)
				Cations (me/l)					Anions (me/l)											
Plot No	Depth (cm)			Na^+	K^+	Ca^{+2}	Mg^{+2}	Total	CO_3^{-2}	HCO_3^-	Cl^-	SO_4^{-2}	Total		Na^+	K^+	Ca^{+2}+Mg^{+2}			
1	0-30	7,73	1985	0,63	0,25	19,38	1,71	21,97	-	12,23	3,02	4,51	19,76	8,95	1,33	1,46	6,16	14,86	37,69	0,37
	30-60	7,80	2135	0,62	0,29	19,12	1,70	21,73	-	11,15	3,20	5,70	20,05	9,42	0,76	1,44	7,22	8,07	37,10	0,37
	60-90	7,87	2180	0,59	0,25	18,86	1,65	21,35	-	10,56	4,86	4,35	19,77	11,71	1,29	1,96	8,46	11,02	37,10	0,35
2	0-30	7,73	3047	0,61	2,70	23,11	5,88	32,30	-	18,36	6,30	7,60	32,26	11,98	1,19	2,47	8,32	9,93	25,67	0,37
	30-60	7,95	3180	0,52	2,40	23,22	5,80	31,94	-	18,54	6,20	7,50	32,24	11,70	1,38	2,12	8,20	11,79	25,66	0,35
	60-90	7,86	3177	0,48	2,32	23,10	5,80	31,70	-	16,50	6,98	5,30	28,78	13,16	1,61	2,50	9,05	12,23	25,60	0,35
3	0-30	7,46	2056	0,58	0,57	16,7	3,75	21,60	-	13,67	3,45	4,75	21,87	9,94	0,76	2,22	6,96	7,65	49,23	0,39
	30-60	7,48	2040	0,55	0,55	16,20	3,65	20,95	-	13,20	4,96	2,55	20,71	10,94	1,15	2,10	7,69	10,51	48,56	0,37
	60-90	7,54	1996	0,58	0,50	15,97	3,62	20,67	-	13,02	4,02	3,60	20,64	9,42	0,80	1,86	6,76	8,49	48,65	0,39
4	0-30	7,65	3084	0,50	0,61	26,17	3,75	31,03	-	14,78	5,87	10,23	30,88	10,23	0,81	1,98	7,44	7,92	7,96	0,25
	30-60	7,56	3060	0,50	0,65	26,38	3,70	31,23	-	15,30	6,22	9,48	31,00	10,12	0,76	2,09	7,27	7,51	7,78	0,25
	60-90	7,38	3074	0,48	0,62	25,96	3,50	30,56	-	13,56	6,24	10,25	30,05	9,56	0,63	1,88	7,05	6,59	7,82	0,25
5	0-30	7,90	2727	0,74	1,11	17,27	8,86	27,98	-	13,22	3,67	10,91	27,80	11,14	0,88	2,37	7,89	7,90	35,17	0,27
	30-60	7,93	2696	0,72	1,02	17,23	8,84	27,81	-	13,37	3,54	9,86	26,77	11,19	1,04	2,35	7,80	9,29	34,50	0,27
	60-90	7,86	2695	0,66	0,95	16,84	8,80	27,25	-	10,66	6,58	9,16	26,40	12,20	1,28	2,66	8,26	10,49	34,20	0,25

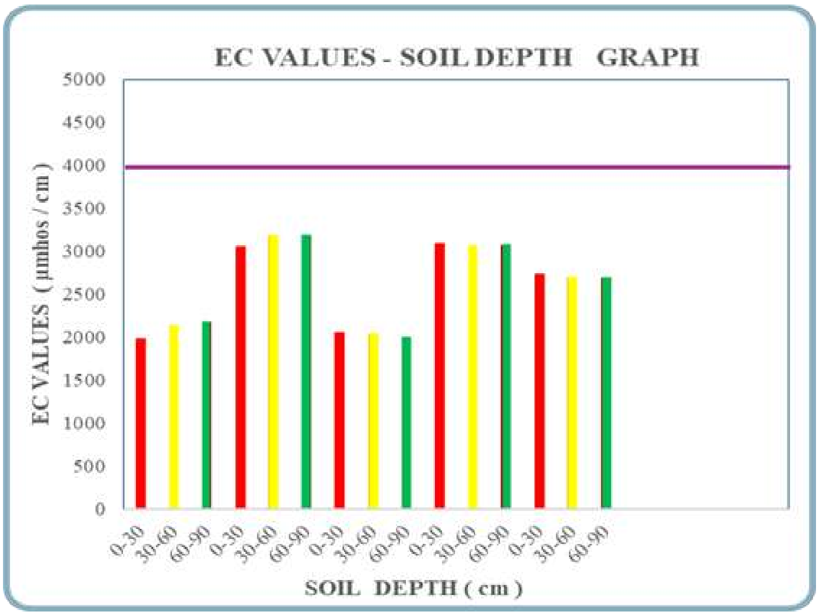

FIGURE 6: Soil EC – Depth relationships

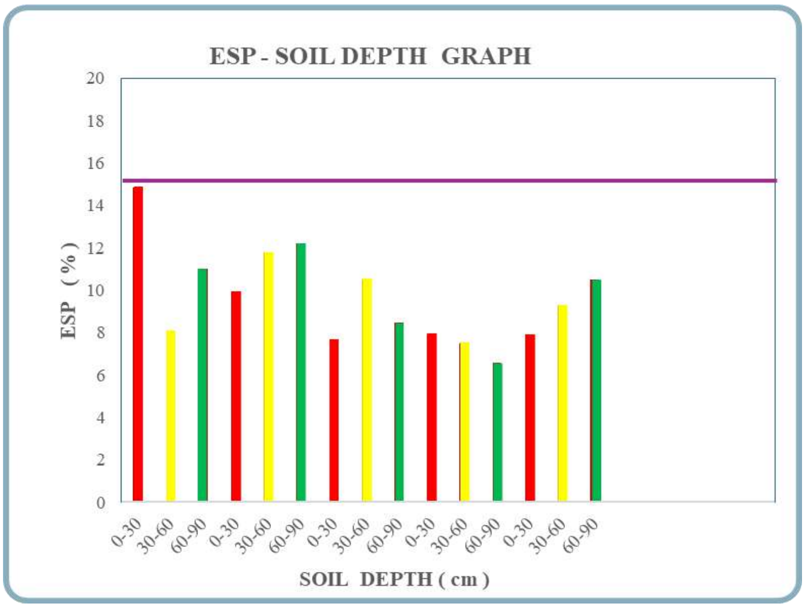

FIGURE 7: Soil ESP – Depth relationships

IV. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusions:

The following conclusions were drawn from the present study conducted to assess the quality of water resources used in irrigation of agricultural fields in Mezitli district of Mersin province.

a) Since the irrigation water samples with a salinity level of below the threshold salinity value of 750 µmhos/cm are classified as **moderately saline waters (C_2)**, these waters are considered to be suitable for use in irrigating the land in these regions. On the other hand, irrigation water samples with a salinity level of above the threshold salinity value of 750 µmhos/cm are classified as **highly saline water (C_3)** and necessary measures should be taken and more salt-tolerant plants should be selected for cultivation when these waters were used in irrigations. The EC values of the present irrigation water samples varied between 292 - 1103 µmhos/cm and the pH values varied between 7.05 - 8.26. Based on these values, the irrigation water quality classes have been determined as C_2S_1 (moderately saline - low alkaline) and C_3S_1 (highly saline - low alkaline).

b) In terms of water-soluble anions and cations, Ca^{++} can be said to be the dominant cation and HCO_3^- the dominant anion. The sodium adsorption ratios (SAR) of the samples ranged from 0.04 to 3.14, while the % Na values varied between 1.51 and 47.99 and the boron concentrations of all samples were below the threshold level of 0.7 ppm.

c) Soil EC values varied between 1985 - 3180 µmhos/cm, pH values between 7.38- 7.95, lime percentages between 7.78 - 49.23, ESP values between 6.59 - 14.86, which were below the threshold value of 15%, boron concentrations varied between 0.25 - 0.39 ppm, which were below the threshold boron concentration of 4 ppm and CEC values ranged from 8.95 to 13.16 me/100 g.

d) Soil textures were identified as loamy (L), clay-loam (CL) and clay (C), with saturation percentages of between 50.45 - 114.35%, field capacity values of between 22.50 - 36.40, permanent wilting point values of between 13.98 - 24.46 and bulk density values of between 1.28 - 1.39 g/cm³.

e) Although some of the irrigation water used for agricultural purposes in the study area was classified as highly saline (C_3), the reason why the soil has not yet become saline is that irrigation has not been carried out at a level that would cause salt accumulation, or that the soil has been well leached.

4.2 Recommendations:

a) New drainage facilities should be installed and periodic maintenance should be performed on existing drainage facilities to prevent salinity problems.

b) Soils should be enriched and soil cultivation methods should be selected appropriately to prevent the organic matter content of soils from decreasing over time.

c) Measures should be taken immediately to prevent salinity and alkalinity problems in agricultural lands and attention should be paid to reclamation and leaching activities.

d) Irrigation should be carried out using appropriate irrigation methods to prevent yield losses. Considering irrigation practices, sprinkler irrigation should be preferred in regions with insufficient water resources, while flooding irrigation should be preferred in regions with sufficient water resources.

e) Relevant institutions and organizations should provide training on soil-plant-water relationships and irrigation water quality to raise farmers' awareness on these issues.

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Study the Efficiency of Moving Bed Bio-Film Reactor (MBBR) for Dairy Wastewater Treatment

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Abstract— *In this research, an experimental study to evaluate removal of COD and BOD from Dairy wastewater by treatment Moving Bed Bio-Film Reactor (MBBR). The paper discusses biological treatment. The objective of the study was evaluation of operational parameters and performance of reactors based on attached growth process by using MBBR. The result shows removal efficiency of Biochemical oxygen demand (BOD), Chemical oxygen demand (COD) and PH were 89%, 84% respectively. The conclusions also indicate that MBBR, with polypropylene media as biofilm carrier, possess great removal Dairy wastewater. The MBBR tanks were filled with suspended plastic carriers, with a 30 to 50% filling ratio. Under optimum conditions, almost complete COD/BOD removal efficiency of 79 % was achieved. This study indicates that its demonstrated that use of this reactor results in removal from wastewater.*

Keywords— Dairy wastewater, Bio-film Media, Biological carrier, COD, BOD, Biomass.

I. INTRODUCTION

A steady rise in the demand for milk and milk products in many countries has led to advancements in veterinary science, which has subsequently led to steady growth in the production of milk per head of cattle. This has caused enormous growth in dairy industries in most countries of the world. Consequently, the amount of wastewater generated and discharged from these industries has also increased.

Two technologies are commonly used for biological treatment of sewage: activated sludge and trickling filters. A moving bed biological reactor (MBBR) is a compilation of these two technologies. The biomass in the MBBR exists in two forms: suspended flocks and a biofilm attached to carriers. It can be operated at high organic loads, and it is less sensitive to hydraulic overloading. The first MBBR was installed in 1989. Although it is a relatively new technology to the United States (first introduced in 1995), there are now over 400 installations worldwide in both the municipal and industrial sectors with over 36 in North America.

1.1 Dairy wastewater:

Dairy industry wastewater is primarily generated from the cleaning and washing operations in the milk processing plants. It is estimated that about 2% of the total milk processed is wasted on drains. The wastewater generated from milk processing can be separated into two groups—the first group concerns wastewater having high flow rates and the second concerns the effluents produced in small milk transformation units (cheese production for instance). Dairy wastewater is characterized by high biological-oxygen demand (BOD) and chemical oxygen demand (COD) concentrations, and generally contains fats, nutrients, lactose, as well as detergents and sanitizing agents. Nutrients lead to eutrophication of receiving water, and detergents affect the aquatic life. Due to the high pollution load of dairy wastewater, the milk-processing industries discharging untreated/partially treated wastewater cause serious environmental problems. Moreover, the Indian government has imposed very strict rules and Regulations for the effluent discharge to protect the environment. Thus, appropriate treatment methods are required to meet the effluent discharge standards.

1.2 Moving Bed Bio-Film Reactor (MBBR):

The basic principle of the moving bed process is the growth of the biomass on plastic supports that move in the biological reactor via agitation generated by aeration systems (aerobic reactors) or by mechanical systems (in anoxic or anaerobic reactors). The supports are made from plastic with a density close to 1 g/cm3 letting them move easily in the reactor even when the capacity reaches 70%. The moving bed processes come from the current trend in wastewater treatment, from the use of systems that offer an increased specific surface in the reactor for the growth of the biomass, achieving significant reductions in the biological reactor volume.

Some factors have been reported to affect the performance of MBBR. The high specific area of the carrier media controls the system performance which is because of very high biofilm concentrations presence in a small reactor volume. It was reported that typical biofilm concentrations range from 3000 to 4000 g TSS /m3, which is like values obtained in activated sludge processes with high sludge ages. The percentage of reactor volume comprised of media is limited to 70%, with 67% being typical (Odegaard et al.,2000). However, wastewater characteristics and specific treatment goals are the main factors determining the percentage of media required in the reactor

II. MATERIAL AND METHODS

2.1 Experimental set-up:

The Moving Bed Biofilm Reactor (MBBR) technology is an attached growth biological treatment process based on a continuously operating, non-clogging biofilm reactor with low head loss, a high specific Biofilm surface area, and no requirement for backwashing. MBBR is often designed as an aerobic system. Samples will be collected from low income and high-income society and its parameters will be evaluated prior to treatment. The proposed experimental set-up for Moving Bed Biofilm Reactor can be made as shown in Fig. 1.

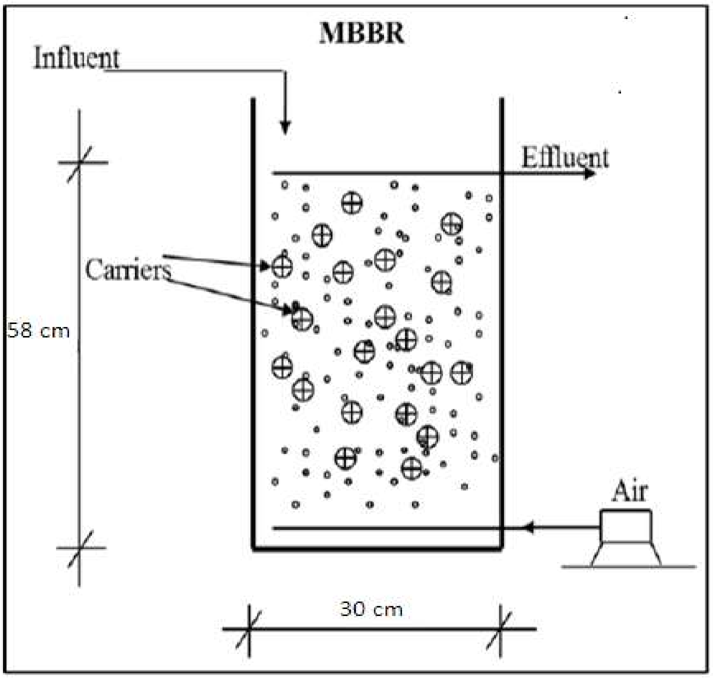
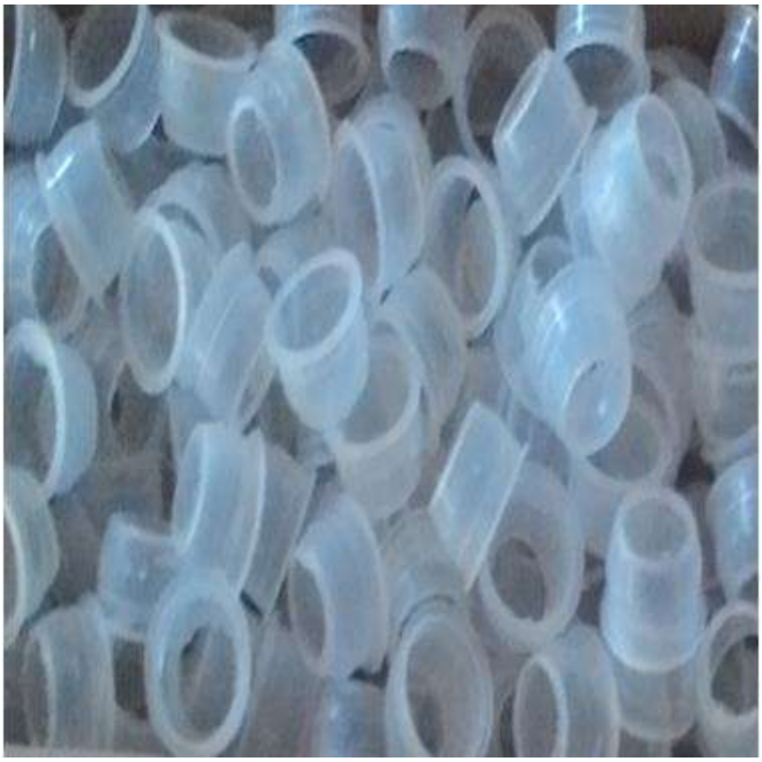


FIGURE 1: Moving Bed Bio film Reactor experimental setup

The Moving Bed Bio-film reactor (MBBR) setup proposed for this study will be made up of plastic containing one compartment. The inlet arrangement for influent after primary treatment of dairy wastewater will be given at the top of tank. The Outlet will be provided at lower level than inlet. The proposed experimental set-up for Moving Bed Biofilm Reactor can be made as shown in the above Figure.

The Moving Bed Bio-film reactor (MBBR) process uses floating plastic carriers (media) within the aeration tank to increase the number of microorganisms available to treat the wastewater compared to conventional secondary treatment. The microorganisms consume organic material. The media provides increased surface area for the biological microorganisms to attach to and grow in the aeration tanks. The increased surface area reduces the footprint of the tanks required to treat the wastewater. The media will be continuously agitated by bubbles from the aeration system that adds oxygen at the bottom of the compartment of the aeration tank. The microorganisms consume organic material. After treatment, final treated effluent will be taken outside through outlet.



Polypropylene carrier **Surface area - 7.144 cm2, cost 340 per/Kg**

FIGURE 2: Characteristics of the bio media

FIGURE 3: Top view of experimental setup

III. RESULT AND DISCUSSION

The characteristics of dairy wastewater taken from after primary settling tank are described in the table. The various tests were conducted on the wastewater as per procedure laid down in standard

TABLE 1
CHARACTERIZATION OF SAMPLE

Sr	Parameter	Method Specification	Permissible Limit	Unit	Result at different sampling days					Average Value
1	pH	Standard Method by APHA Ed.2nd.2012,4500 - H+B	6.5-8.5	-	8.2	8.0	7.8	8.0	7.5	7.9
2	COD	Standard Method by APHA Ed.22nd .2012,5220-B	250	Mg/l	980	950	870	935	1050	957
3	BOD	Standard Method by APHA Ed.22th .1998,5220-B	30	Mg/l	435	450	470	506	525	478

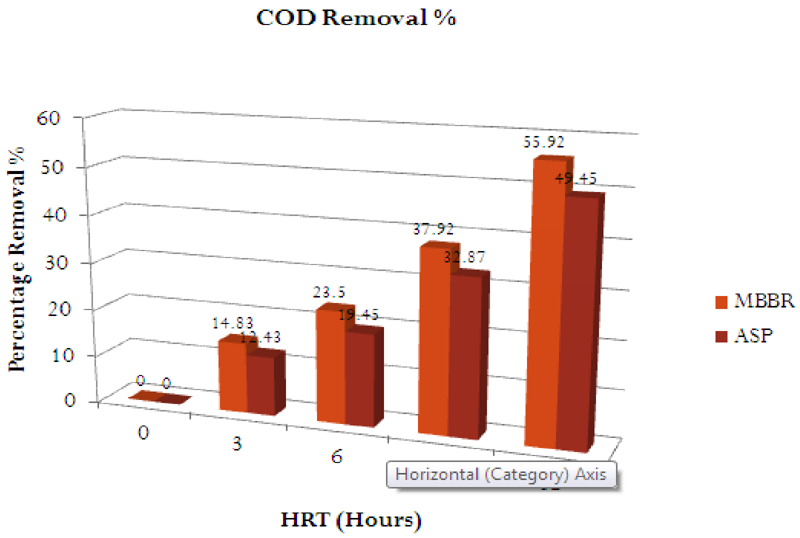


CHART 1: Compression of COD Removal % between MBBR and ASP

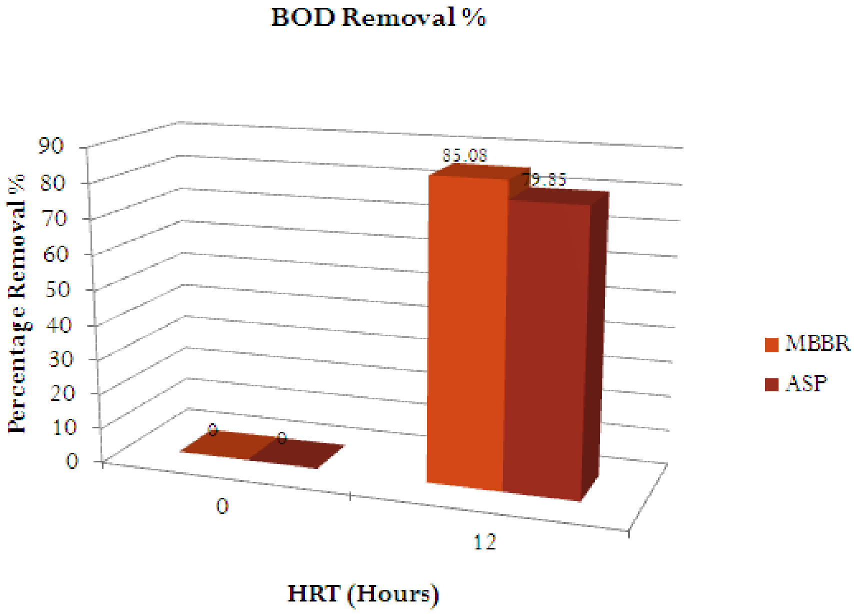


CHART 2: Compression of BOD Removal % between MBBR and ASP

IV. CONCLUSION

This study confirmed that the MBBR was highly effective on removing BOD up to 71 mg/L and COD at up to 171 mg /L at 12 hours detention time with a removal efficiency of BOD is 85%, and COD is 55% for dairy wastewater. Reductions in TDS and TSS were not significant. And as compared to Asp this treatment is best giving and for more biomasses grow its more effective result more 90% as less duration. Initially the pH of Dairy waste sample was more alkaline but due to the techniques implemented the pH was brought up much near to the neutral axis. Organic matter removal was generally higher in systems, suggesting that plants may play an important role in removing organic matter from MBBR. So, the treated waste can be effectively used for irrigation and local purposes. Hence, the MBBR treatment process may prove to be a handy solution for the organic effluents from food-based industries.

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Diminishing Size of Wetlands: A Review of their Rehabilitation in Africa

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Abstract—

Introduction: *Wetlands are one of the world's most essential type of ecosystems and are also the most vulnerable. Their role is functionally critical in climate change, biodiversity, hydrology and human health.*

Problem Statement: *The degradation of wetlands is beyond doubt a certainty and our conducts are the main factors to lay blame on. Current world research estimates that 50% of the Earth's wetlands have vanished.*

Methodology: *This review article is essentially a qualitative in complexion, using secondary data. The review will go through definitions, theories, global current state and extent of wetlands; African wetlands and their background, threats and future, rehabilitation through to conclusions and recommendations.*

Results: *The plans for the management of marshlands in the world are unimpressive especially in Africa and Asia. There is need for working together, holistically, at all levels to bolster global wetlands conservation and restoration.*

Conclusion: *The pressure on wetlands is increasing all over Africa due to population explosion. The survival of wetlands in Africa lies in a stronger political will. This is to be based on wetland policies and encouragement for community participation in their management. Countries in Africa are subscribing to the Ramsar Convention, indicating a willingness to sustainable wetland management.*

Keywords— Marshlands, Restoration, Degradation, Swamps, Ecosystem.

I. INTRODUCTION

The academic [1], have produced a figure that states that wetlands around the world have been degraded by about 87% in the last century and a half in data existing regions. A Report from [2] and [3] has confirmed that we have lost more than half of the wetlands and the loss mainly occurred in the 20th century. A report from the Ramsar Convention Secretariat gives a figure of 35% reduction of global wetlands, with data available during the period 1970 and 2015 [4]. This shrinkage (and gradual extinction) of wetlands is not a new experience however its alarming shrinkage rate has not been widely felt until recently.

Wetlands are one of the world's most crucial and important types of ecosystems and also one of the most threatened. Climate change, biodiversity, hydrology and human health rely heavily on the functions and well-being of wetlands [5]. It is a fact that wetlands exert an effect on global and climates by supplying the atmosphere with potential or near-potential evapotranspiration and by taking up carbon dioxide and emitting methane [6]. From the aspect of biodiversity, although freshwater wetlands cover only 1% of the earth's surface, they are a home to more than 40% of the Earth's species [7]. Hydrologically, wetlands serve to replenish groundwater, regulate water movement, and purify water, providing these important parts with an important hydrologic cycle [8]. As regards to human health, wetlands supply traditional medicines on which 80% of the world's population depends on for primary health care [7]. Previously, humans have regarded wetlands as a harbour of mosquitoes, carriers of disease and sources of death [9; 10].

Wetlands fall into two broad categories namely natural and artificial (constructed) [10]. Natural wetlands are the original areas where water covers the soil, including swamps, marshes, fens, sloughs, and bogs while constructed wetlands are ecosystems (man-made) similar to natural wetlands, combining physical, chemical and biological processes [11]. Wetlands exhibit themselves in a number of ways that include areas of marsh, fen, peatland and shallow water bodies, [12].

As compared to rain forests and coral reefs, wetlands are among the most productive ecosystems in the world [12]. It is confirmed that marshlands bring a source of substantial biodiversity, giving life to numerous species ranging from microbes to mammals [13]. Physical and chemical features such as climate, topography (landscape shape), geology, nutrients, and hydrology (the quantity and movement of water) help to determine the plants and animals that inhabit various wetlands, [11]. Despite all of their functions wetlands have been faced with destruction, if not extinction especially in Africa. Threats to wetlands in Africa can largely be attributed to human activities, though climate change and variability also play a part.

Wetlands are known as areas that are waterlogged by surface or ground water, either permanently or seasonally. It is stated by [14] that a wetland is an area of mainly saturated soil that can support the prevalence of hydrologic soil adapted plants. Wetlands are perfect combination of water and land and are the most biologically diverse ecosystems in the world [14]. There are many kinds of wetlands, including swamp, marsh and bog which are filled with trees, shrubs and moss. Functions of wetlands include:

- Provide habitat for a wide variety and number of wildlife and plants.
- Filter, clean and store water. In other words acting like kidneys for the ecosystems.
- Collect and hold flood waters
- Absorb wind and tidal force
- Provide places of beauty and many recreational activities [15].

By holding flood waters and keeping rivers at normal levels, wetlands behave like sponges [14]. They are able to filter and purify water as it flows through the wetland system and the plants found in wetlands help control water erosion [15]. On our world, the existence of wetlands has very positive effects for the biologically diverse.

Wetlands are among the most productive ecosystems on Earth. They allow interaction between water, soil, vegetation and light all year round or during a greater part of the year. The depth of the water is such that it allows photosynthesis to occur, making wetlands productive life-supporting ecosystems.

Wetlands were the first ecosystems to receive international attention through the "*Convention on Wetlands of International, Importance Especially as Habitats of Waterfowls"*, which opened for signatories at Ramsar, Iran in February 1971 [16].

Rapid urbanisation and abuse of natural resources have degraded the wetlands [17]. The North American Wetland Conservation Act was passed in 1989 by the United States of America (USA) Congress to stop the destruction of wetlands and other types of habitats [18]. It is estimated that nearly half of available wetlands have already been destroyed because of the increased demand for land as a result of rapid population increase [18]. Evidence is abound that thousands of hectares of wetlands are converted to farmland, residential and, industrial areas every year.

The size of the wetlands (inland valley swamps) in Africa is potentially approximately 135 million hectares, and luckily only about 1.3% of this is under cultivation. The reasons for this include lack of appropriate water management and other agro-technologies, health risks, the complexity of these fragile ecosystems and an overall unfavourable socio-economic environment [18].

Globally it is quoted, but there is lack of verifiable facts or evidence, that the world has lost 50% of its wetlands (or 50% since 1900 AD) [1]. It is known that the rate of wetland loss has been 3.7 times faster during the 20th and early 21st centuries (approximately between 64-71% of wetlands have been lost during this period) [17]. The pace of wetland loss in Europe and North America has slowed down, since the 1980s, but it has remained high in Africa and Asia where large-scale and rapid conversion of coastal and inland natural wetlands are continuing [18]. There is a need to improve the knowledge of change and awareness in wetland areas worldwide, particularly for Africa, Neotropics and Oceania, and to improve the consistency of data on change in wetland areas in published papers and reports [18].

Man-kind has been training, in filling and converting both coastal and inland wetlands for many centuries, for example, since the Roman times in Europe [19]; the 17th century in North America [20] and Southern Africa [21] and for at least 2000 years in China [22]. As this transformation and degradation of wetlands continues, with the underlying drivers being:

- Economic and human population growth and proximate causes being transformation at first to extensive and intensive agriculture (croplands),

- Changes in water use and availability (including the downstream effects of water abstraction and major hydro-engineering schemes),
- Increasing urbanisation and infrastructure development, disease control (especially for mosquitoes – to control malaria) and spread of invasive species,
- On the sea coast defences, port and industrial developments and industrial developments and aquaculture [23]; [24].

The prevalent (not quantified) inland and coastal wetland drainage and transformation and particularly its impact on hunted waterfowl populations has been increasingly reported and raised as a concern since the 1920s in North America [25] and from the early 1960s in Europe [26]; [27]. It was concluded that in temperate regions drainage of wetlands is proceeding at an increased rate and without reference to their diverse values and recommended the establishment of an international convention on wetlands [27]. This led in 1971 to the global scope establishment of the Ramsar Convention on Wetlands [28], which appreciated the great importance of wetlands, the loss of which would be irreparable, to people and which has the desire to stem the loss and degradation of wetlands now and in the future, through the wise use of all wetlands, the designation and management of Wetlands of International Importance (Ramsar Sites) and international cooperation [29]; [30]; [31]. The Convention has now aggregated to 168 governmental participating parties which have designated 2303 Ramsar Sites covering over 228 million hectares of wetlands and associated habitats. See Table (A).

TABLE (A)
THE NUMBER AND AREA OF WETLANDS. SOURCE: RAMSAR OFFICIAL WEBSITE 2019

Continent	Number of Wetlands	Area (million hectares)
Africa	397	110
Asia	368	27.5
Europe	1004	14.2
North America	309	28.9
South America	146	39.6
Oceania	79	8.6
TOTAL	2303	228.8

Although officially Ramsar Sites are protected, unfortunately, they do face threats. The impact of dynamics of wetland can be divided into wetland transformation and wetland destruction [3]. In most instances the dilapidation of wetlands is affected by destructive factors, such as agriculture, infrastructure development, water use and pollution [32]; [33]; [34]; [24].

By 1985, almost 56% to 65% of wetlands in Europe and North America were drained for agriculture, with Asia, South America and Africa having 27%, 6% and 2% respectively [35].

The total wetland area of thirty Ramsar Sites in Africa has declined by just two thousand hectares, however, wetland ecosystem disintegration is more serious [33]. Seventeen percent of the river wetlands and 20% of the inland flood wetlands have degraded into non-wetlands [35]. The disturbance degradation index in Africa is high and keeps constantly increasing [36]. The Lake Chad, for example, an African transnational lake, suffered a 9% drop in lake surface and an 89% drop in seasonal herbaceous swamps between 2001 to 2013, which mainly was due to drought and drainage for irrigation [36]. The signal site with the largest area is the Ngiri-Tumba-Maindombe, located in the Democratic Republic of Congo (DRC) [37]. Now this area is under apparent threat because of pressure from the rapidly growing population and illegal mining activities, for example [38]. Climate, topography (landscape shape), geology, nutrients, and hydrology (the quantity and movement of water) are physical and chemical features that help to determine the plants and animals that inhabit various wetlands, [39].

II. PROBLEM STATEMENT

The loss by degradation of marshlands is an indisputable reality and human activities are chiefly to blame as the main factors. A lot of research has indicated that 50% of the world's wetlands have been lost, although this is based on inadequate supporting evidence [40]; [1]. This figure originates from very limited data gathered solely from the USA and solely during the mid-20th century.

The wetland reduction and degradation is ongoing unabated, and due to this the world's population is being deprived of the ecosystem services that marshlands provide. It is estimated that more than US$20 trillion is lost annually via destruction of the wetland ecosystems.

Luckily, Africa still possess a substantial number of pristine wetlands, when compared to Europe or parts of North America. Human activity, however, is still putting a lot of pressure on some wetlands, the major culprit being drainage for agriculture and settlement, excessive exploitation by local communities and improperly planned development activities. In spite of the noted importance of wetlands to local communities the human pressure on wetlands is expected to increase as populations grow, unless strategic actions are put in place for the conservation of wetlands.

III. METHODOLOGY

The question this paper seeks to find out is that *"can we, as mankind, be able to rehabilitate or restore wetlands to their original state and size, if not what are the consequences?"* This research review is essentially a qualitative approach and is based primarily on literature review from secondary data sources. It must be noted and observed that since the review is a qualitative in complexion where the research methods have been used to gather non-numerical data and to find meanings, opinions and underlying reasons vary from various sources. It is based mainly on, concerned with and verifiable by observation and experience rather than theory or pure logic.

In order to understand more about wetland rehabilitation and restoration, literature will be drawn from journals, handbooks, working papers, published and unpublished theses, as well as publications from the global wetland scenarios (for example, Ramsar Secretariat) and government documents drawn from the whole world including Africa.

The underpinning issues upon which this review article is based on include the size, distribution and extent of wetlands (natural and artificial) both globally and on the African continent, threats, values, restoration, rehabilitation and policy considerations.

This paper defines wetlands, discusses theories that guide ecological restoration and rehabilitation, current state, distribution and size (extent) of wetlands, the African wetlands and their background, threats to wetland biodiversity and their future, government and private agencies endeavours plans on rehabilitation/restoration, human activities connected with wetlands extinction, policy and monitoring issues in Africa through to conclusions and recommendations.

IV. LITERATURE REVIEW

4.1 Defining wetlands:

The term wetland is haze. Scholars diverge and converge in trying to give a comprehensive definition of the term. Different scholars give different attributes of wetlands. The International Water Management Institute [41] cites the availability of numerous interpretations of what the make-up of a wetland around the world. Wetlands measurements and mapping techniques also vary between countries and regions. It is argued that there are two dimensional basis of defining wetlands, namely ecological studies and management purposes [42]. The commonly adopted definition however, which is considered to be encompassing, is given by The Ramsar Convention. The Ramsar Convention [43] defines wetlands as areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.

For wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water [44]. In another dimension [45] defines wetlands as areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands are defined by [12] as natural areas where water covers the soil, including swamps, marshes, fens, sloughs, and bogs. In another dimension The New Zealand Resource Management Act in [13] defines wetlands as permanently or intermittently wet areas, shallow water, and land water margins that support a natural ecosystem of plants and animals adapted to wet conditions.

4.2 Theories that Guide Ecological Restoration:

The extent of ecosystem degradation necessitates the development of restoration science and the growing body of literature on ecosystem restoration is an opportune moment to put ecological theory into practice. The inclusion of this section is crucial and important to make justice to this paper. It is conceptualized by [46] that ecosystem restoration as 'a process of shifting an ecosystem along a trajectory from degraded to historical conditions, notably structure-function model'. Ecosystem restoration happens in stages and [47] asserts that these are: (1) Goal setting; developing the conceptual model, (2) Prioritizing sites for restoration within the region, (3) Manipulating abiotic conditions on site, (4) Manipulating the biota on site, (5) Ecosystem maintenance. Under each stage, there are drivers and theories that can be applied in the restoration process and these theories are listed below:

- Theory 1 Suitability Model – restoration to damaged lands can be restored and modified to mimic some model.
- Theory 2 Biodiversity-ecosystem function – restoration projects must ideally target higher biodiversity in order to enhance broader ecosystem services.
- Theory 3 Eutrophication – excessive nutrient environment in restoration sites is not desirable and it must be emphasised that nutrients are sometimes delivered through unorthodox means (like via industrial waste).
- Theory 4 The reversibility of degradation – restoration process can be successful if it capitalises on opportunities that have the potential to derive maximum benefit. According to [48] whenever resilience thresholds are exceeded or ecological buffeting mechanisms are overwhelmed, the biophysical components of ecosystems may not recover to their prior state.
- Theory 5 Island biogeography – asserts that larger islands have higher colonization and lower extinction rates and sustain more species than small islands [49].
- Theory 6 Niche - According to [50], theory concerns those characteristics that define where a species lives and how it functions. This theory mainly applies to terrestrial fauna which often requires multiple habitats within a single year due to seasonality.
- Theory 7 The manipulation of abiotic site conditions - the restoration process of terrestrial ecosystems must start with a process of manipulating abiotic site conditions before flora species are introduced.
- Theory 8 Topographic heterogeneity - this theory asserts that restoration sites can be configured in a way that accelerate succession. Thus, heterogeneity in topography can provide more niches to support a wider variety of species and hence, fast track the process of restoration.
- Theory 9 Secondary succession – this is the replacement of a desired species by another more aggressive or adaptive species in an ecosystem. According to [51], species that succeed primary species usually have better dispersal capability, higher germination rates, demonstrate allelopathy and have.
- Theory 10 Assembly – this is closely related to the theory of succession and this assertion is supported by [52]. The conditions needed for flora species to thrive can vary considerably from those of the regeneration niche.
- Theory 11 Invasion – concerns the susceptibility of sites to invasion and the persistence of species that would have been introduced.
- Theory 12 Food Web dynamics – the success of a restoration project is hinged on the dynamics that happen within the food web can alter the dynamics of the food web and keep the restoration project on target or derail it.
- Theory 13 Further biotic manipulations – in the restoration process, locally adapted flora and fauna species must be preferred over foreign ones for introduction to restoration sites [53]

- Theory 14 Resilience – this is derived from in-situ mechanisms and some ecosystems recover more easily from frequent disturbances than others. Restored ecosystems must be guarded from such shocks and disturbances through constant monitoring to enhance resilience.

4.3 Advancing Restoration Ecological while improving Ecological Restoration:

Ecological restoration usually advances an array of multi-dimensional goals, ecological conditions and let be known that restoration will result in multiple pathways with multiple outcomes [47]. In order to achieve desired restoration targets more restoration sites must be designed to address challenges [54]. Mostly, forecasts or predictions of restoration pathways and outcomes are very general and actual pathways are specific to the site, the target, the species employed, and the resources invested [47]. The outcomes of ecological restoration are never exact matches of the system targets since ecosystem behaviour cannot be predicted with such exactitude [55]. Large restoration projects offer the opportunity to design programmes to sequentially so that the results are more predictable [55]. In this approach of adaptive restoration, each phase of the restoration process is designed as a series of experimental plots that test alternative restoration methods [56]. Thus, restoration ecology can be advanced by designing and implementing restoration projects as experiments.

4.4 Current State and Size of Wetlands:

Reviewed information on the size and distribution of wetlands shows considerable inconsistency in the information obtained for scrutiny, with data unavailable for some countries due to lack of adequate maps [57].

TABLE 1
GLOBAL AREA ESTIMATES OBTAINED FROM WETLAND INVENTORY SOURCES (PRIOR TO YEAR 2000)

Source	Region	Wetland type	Global area (hectares)
[58]	Asia, Oceania, Africa, Europe, Neotropics, America.	Forested bog Nonforested bog Forested swamp Nonforested swamp Alluvial formations Total natural wetlands (excluding irrigated rice fields)	207 800 000 89 700 000 108 700 000 100 700 000 19 400 000 530 000 000
[59]	Asia, Oceania, Africa, Europe, Neotropics, North America.	Rice paddies Bogs Fens Swamps Floodplains Marshes Lakes Total natural freshwater wetlands	130 000 000 190 000 000 150 000 000 110 000 000 80 000 000 27 000 000 12 000 000 570 000 000
[60]	Asia, Oceania, Africa, Europe, Neotropics, North America	Wetlands (assumedly freshwater only)	560 000 000
[61]	Asia, Oceania, Africa, Europe, Neotropics, North America.	Wetland sites on the Ramsar List of Wetlands of International Importance	52 334 339
[61]	Asia, Oceania, Africa,, Neotropics, North America	Mangroves only	18 100 000
[61]	Asia, Oceania, Africa, Neotropics, North America	Coral reefs only	30 000 000 – 60 000 000
[60]	Asia, Oceania, Africa, Europe, Neotropics, North America	Peatlands only	400 000 000
[62]	Asia, Oceania, Africa, Europe, Neotropics, North America	Artificial wetlands – rice paddies	130 000 000

TABLE 2
REGIONAL WETLAND AREA ESTIMATES BY WETLAND TYPE (PRIOR TO YEAR 2000)

Region	Wetland type	Continental area (ha)	Source
Africa	Freshwater wetlands Freshwater wetlands Tropical swamps Headwater swamps Floodplains Swamps Shallow waterbodies	34 500 000 35 600 000 >34 000 000 8 500 000 10 980 000 12 640 000 2 830 000	[62] [59] [63] [63] [63] [63] [61]
Asia	All wetlands	>120 000 000 >7 517 300	[59] [58]
Oceania	No regional estimates at that time		
Europe	Freshwater wetlands Coastal salt marshes	670 000 230 000	[64]
Canada USA North America total	All wetlands Marine wetlands Estuarine wetlands Palustrine wetlands All wetlands	127 200 000 31 741 2 123 199 37 949 958 >167 304 898	[62] [62] [62] [62] [62]
Caribbean South America Central America Neotropics total	All wetlands Freshwater wetlands Freshwater wetlands All wetlands	23 500 000 152 000 000 1 750 000 >177 250 000	[61] [63] [63] [62]

Africa has an estimated total 345000 km^2 (34.5 million hectares) of wetlands (one percent of its total area), including a number of very large swamp systems [65;66]:

TABLE 3
AFRICA'S LARGE SWAMP SYSTEMS

Location	Area km^2 (million ha)	Type
The Upper Nile	92000 (9.2)	Swamp including floodplain, of which 40000km^2 (4million ha)
Lake Bangweulu	6000 (600000hectares)	Swamp and 6000km^2 (600000 hectares of floodplain)
Okavango Delta	16000 (1.6)	Swamps and islands
Uganda	11800 (1.18)	Network of swamps
Zambia	750000 (75)	Swamps covering 24000km^2 (2.4 million ha), Pans and including dambos 35000km^2(3.5 million hectares)

Source: [63], [64]

But [67] provide areas for seven of Africa's largest swamps, which total over 60000 km^2 (6 million hectares) of permanent swamp and greater than 400000 km^2 (40 million hectares) of seasonally inundated swamps. They reported an estimate of 340000 km^2 (34 million hectares) of tropical swamps in Africa, noting that this estimate is perhaps underestimated by up to 30%. They considered an estimate of 85000 km^2 (8.5 million hectares) for head-water swamps in Africa in the same period to be accurate.

4.5 African Wetlands:

The Africa discussed in this review document consists of the mainland continent and the islands of Cape Verde, Comoros, Madagascar, Mauritius, Sao Tome and Principe, and Seychelles, totalling up to 53 states and 23 of which are Contracting members of the Ramsar Convention. The wetlands of Africa form only one percent of the total continent's surface area, this excludes coral reefs and some of the smaller seasonal wetlands [62]. There has been relatively little scientific research undertaken in them in comparison to other ecosystems as such forest or wetlands in other parts of the world [62]. The wetlands' critical function in support of the regions' biodiversity and the livelihood of large human populations is becoming increasingly clear from on-going studies [61].

The greatest concentration of wetlands are found between 15^0 North and 20^0 South and includes some rather spectacular areas:

- wetlands of the four major riverine systems (Nile, Niger, Zaire and Zambezi);
- Lake Chad, and wetlands of the Inner Niger Delta in Mali;
- the Rift Valley Lakes (Victoria, Tanganyika, Malawi, Turkana, Mweru and Albert);
- the Sudd in southern Sudan and Ethiopia
- and the Okavango Delta in Botswana,

All of the above do display a richness and uniqueness in biodiversity [68].

4.6 Biodiversity in African Wetlands:

The biological diversity of wetlands in the continent is evenly distributed, with some habitats being characterised by a richer range of species than others and especially wetlands in areas of high rainfall and warm climates, for example, the Congo Basin, display a richer species diversity than those of drier regions north and south of the 15^0 North to 20^0 South [69]. The critical role of a wetland from a biodiversity point is judged not only by the overall richness in number of species present, but on the uniqueness of the area in terms of the number of localised species present, particularly the endemic species [70]. The majority of the continent's wetlands reveal both characteristics richness in a number of species and endemism [70]. There are, for example, over 2000 known species of indigenous freshwater fishes in Africa [61]. The Zaire River Basin, probably the most diverse area in Africa for its fishes has over 700 identified species of which 560 are endemic to the basin [61].

It has been noted by some authors and researchers that wetland areas of highest endemism and of international significance in Africa are found in the inner Niger Delta in Mali, the seasonally inundated floodplains of northern Central African Republic and southern Chad, the Sudd region of Southern Sudan, Lake Victoria and Kyoga in Uganda, the swamps of western Tanzania and various parts of Zambia, and the Okavango region of northern Botswana [71].

The same can be said of the role of wetlands in Southern Africa in supporting a wide range of biodiversity is similarly recognised [72]. For example, in Zambia's Bangweulu Basin are important populations of the threatened Black Lechwe (*Kobus leche smithemani*) and Shoebill Stork (*Balaeniceps rex*) (the later also found in Lake George, Uganda) [73]. The St Lucia System wetlands of South Africa, exemplifies biodiversity rich estuarine wetlands in Africa and boasts great diversity of plant life in its freshwater reed and papyrus swamps, freshwater swamp forest, tidal swamp forest grasslands, mangroves and riverine woodlands [74]. At least over 350 bird species, more than 180 species of estuarine fish and 38 freshwater fish as well as significant populations of hippopotamus and crocodile are supported by this plant diversity [75].

According to [75], the Sahel wetlands of western Africa are concentrated mainly in the Senegal River Basin in Senegal and Mauritania, the Niger River Basin in Mali and Lake Chad and the Logome and Chari rivers in Cameroon, Nigeria and Chad, and they have abundant food source and attractive habitats, which host numerous endemic and migratory waterfowl [75]. The floodplains of the Senegal, Niger and Chad Basins, for example, support over a million waterfowl while the Djoudj National Bird Park, Senegal and Diawhig National Park, Mauritania, are havens for migratory birds in West Africa, providing habitat for over three million birds belonging to nearly 400 species [65].

The Sebkhet el Kelbia in Tunisia also exhibit the unique shallow depressions in the arid and semi-arid pasts of North Africa [76]. These are characterized in wet years by a high primary productivity and a diversity of habitats and natural resources which enables them to support a large number and diversity of migratory, wintering and nesting birds [65].

4.7 The Values of African Wetlands:

4.7.1 Wetland values and benefits

According to recent research by [77], the value of marshland/wetland ecosystem services decreased by US$9.9 trillion per year during the period 1997 to 2011. Globally the degradation of wetlands will produce huge economic losses.

The secondary values focused by [65], namely economic value lays importance of wetlands to human communities/populations. The importance of this value is very clearly demonstrated in Sub-Saharan Africa, where many people survive by exploiting natural resources of wetlands [65].

It is therefore not surprising that communities heavily rely on wetlands for a large variety of goods and services. For example, they provide people with fertile soils for agriculture, with fish to eat, with wood for fuel and with reeds for mats and roofs [78]. In addition wetlands are able to keep/store water temporarily and recycle nutrients and human waste to improve water quality [77]. Famous wetland areas like the Okavango Delta in Botswana and the Pantanal in Brazil attract large numbers of tourists each year for recreational activities like bird watching or safaris as well as for scientific study [77]. In the next section, one such tropical wetland in Kenya is highlighted to show the importance of wetlands for local people (See Table 4).

TABLE 4
WETLAND FUNCTIONS

Function Type	Wetland Good, Service or Attribute
Regulation Functions	Storage and recycling of nutrients; Storage and recycling of human waste; Storage and recycling of organic waste; Ground water recharge; Natural flood control and flow regulation; Erosion control; Salinity control, Water treatment; Climatic stabilization; Maintenance of migration and nursery habitats, Maintenance of ecosystem stability; Maintenance of integrity of other ecosystems; Maintenance of biological and genetic diversity
Carrier Functions	Agriculture; Stock farming (grazing); Wildlife cropping/resources; Energy production; Transport; Tourism and recreation; Huma habitation and settlements
Production Functions	Water; Food; Fuelwood; Medicinal resources; Raw materials for building, construction and industrial use; Genetic resources.
Information Functions	Research, education and monitoring; Uniqueness, rarity or naturalness and role in cultural heritage

Source: [78]; [79]

The economic assessment research purpose was to enumerate present and potential economic benefits of wetland resources and services in order to balance them with the potential gains from its conversion and modification for industrial and residential development [1]. Five wetland resources were valued (crop cultivation, papyrus harvesting, brick making and fish farming; and services) and one wetland service (purification and treatment of wastewaters) [1].

TABLE 5
WETLAND VALUES

Wetland Resource	Description
Crop cultivation	The wetland provides water required for irrigated crop cultivation and deposits sediments and nutrients, which maintain soil fertility. Three quarters of the reclaimed area has been turned over to crops, and about one quarter for settlement. Approximately 1.8km^2 of the wetland is crop area of which about 450 to 500 farmers grow crops. In permanently water logged areas, mainly cocoyams and sugarcane is grown; in drier areas, crops grown include sweet potato, matooke, mixed vegetables and cassava.
Papyrus harvesting	Approximately fifty people in the wetland harvest papyrus, which generates income in three ways (1) half of the harvesters sell raw materials to artisans such as thatchers and mat makers (2) a quarter of the harvesters produce rough low cost mats; and (3) another quarter of the harvesters produce fine, high cost mats
Brick making	About fifty people make bricks for building during the eight dry months of the year.
Fish farming	There are two fish farms in the wetland area
Water treatment and purification	The largest waste that enters the wetland is domestic waste, which is organic. Furthermore, one-third of the fifteen industries plus 200 smaller production facilities discharge waste directly into surface water. Wastes include detergents, lubricants, oils, acids, xenobiotics, nitrates, phosphates and heavy metals. The wetland treat and purify the water.

Source: [1]

In Africa the wetlands have various goods and services that have an economic value to the rural community living in its periphery but also to communities outside the wetland area [74];[79]. The economic value of these goods and services can be quantified through economic valuation studies. The worthiness of the wetlands commodities that are traded on the market place, such as fish, can be valued through the market price of the resource [82]. On the African continent a lot of the resources and services provided by the wetlands are not traded in the market place and economic theory offers shadow-pricing methods that allow for the economic valuation of such important services as retention capacity and water cleaning capacity of wetlands, and wetlands as nurseries [79]. The outcomes of economic valuation research can be assessed against other land and water uses, including the reclamation of wetlands or the diversion of water from wetlands for the purpose of agriculture [83].

TABLE 6
EXAMPLE OF ECONOMIC VALUES OF WETLANDS

Wetland	Area km^2	Total Economic Value (2018 US$/year *1000)	Economic Value per km^2 (2018 US$/year *1000)
Lake Chilwa Wetland	2 400	29 478.96	12.32
Zambezi Basin Wetland	29 829	281 755.32	9.38
Hadejia - Jama're Wetland	3 500	22 191.26	6.44
Nakivubo Wetland	5.29	1 482.46	264.60

Source: [82]

Table 6 shows that the economic values per km^2 for the first three Wetlands are in similar range but the Nakivubo Wetland in Uganda has extremely high economic value per km^2 [82]. This is due to the value of the wetland service provided, that is, water treatment and water purification. This has been brought up by the applications of two methods: replacement costs in case this wetland service disappears and mitigative expenditure required to offset the effects of a loss in water quality when the wetland is lost [82]. This provides a range of US$700 million to US$1300 million per year, which contributes 88% to 93% to the total economic value [82].

Examples of the Many Uses of the Biodiversity and Productivity of African Wetlands by Local Communities [76]

- In Uganda people harvest Cyperus to make mats and baskets
- In Rwanda Cyperus papyrus is compressed into fuel briquettes with a high calorific content
- In the Okavango Delta roots, palm Hyphae, Phragmites, and palm hearts are harvested for subsistence foods, wine and in southern Africa, the vegetation is rich and diverse, and water lily tubers, bulrush building material. Over six thousand local people are employed in tourist camps in the Okavango Delta
- In the Inner Delta rice, millet, maize and wheat are cultivate in the highly productive soils of wetland areas

Human beings are not the only creatures that benefit from the high plant productivity in wetlands, for example in the Kafue Flats of Zambia, the local herdsmen graze their cattle on 40% of the highly productive *Vossia/ Echinochloa* vegetation, while the endemic Kafue Lechwe Kobus (*leche kafuensis)* grazes more than 80% of the Paspalidium water meadow [74]. It is of a big advantage that large animals depend heavily on the African wetlands because this brings immense economic value to African countries since these mammals are the mainstay of the tourist industry. Included amongst these animals are elephants, buffaloes, antelopes, crocodiles, hippos, and zebras and the major predators, lions, wild dogs and hyenas. The survival of these large mammals are often inextricably linked to wetlands. For example [17], the Amboseli swamps in Kenya are the only water source for animals in the surrounding area. Equally, the rich, riverine vegetation of the Masai Mara Game Reserve supports antelope and other mammals during the dry season [17].

4.8 Threats to wetlands:

The majority of stock list of materials in the Africa region do not show the major threats to wetlands on the continent. For instance, location based researches do provide very brief descriptions of threats to individual wetlands; usually these studies are the ones undertaken to designate or describe wetlands of 'international importance'; according to the [83]. The standard site descriptions are recorded on a Convention-approved form, the 'Ramsar Information Sheet' (RIS) and this proforma includes an information category called 'Adverse factors'[94]. This subject is recorded in the Ramsar Database according to an ad hoc set of past (but still influential), present and/or potential wetland threats (both in and around the site), and these were based on the data that have been provided, rather than fitting incoming data to a pre-existing structured classification [83].

4.9 Major Threats:

From about 1900, at least more than fifty percent of the Earth's wetlands have vanished [84]. These losses are a result of: (1) the public nature of many wetlands products and services; (2) user externalities imposed on other stakeholders; and (3) policy intervention failures due to a lack of consistency among government policies in different areas, including economics, environment, nature protection and physical planning [85]. In the USA, it is estimated that fifty-four percent of its previous wetland areas have been lost, mostly to development in agriculture (87%) and 8% to urban development [97]. During the same period France has lost 67% of its wetlands, while the Netherlands has lost 55% of its wetlands in only 35 years between 1950 and 1985 [87]. In Africa the wetlands loss figures are barely known, but it is expected that the pattern of wetland conversion is similar to that of the United States (54%). In Africa, the Niger for example has lost more than 80 % of its freshwater wetlands over the past three decades [78]. Although some past conversions might have been in society's best interests, wetlands have frequently been lost to activities resulting in limited benefits or costs to society [87].

Primarily the major cause of the wetland conversions is the fact that they are numerous stakeholders of wetlands with different interests that lay claims on the wetlands' functions that do not always coincide. Table 7, shows nine groups of stakeholders identified by [86]:

TABLE 7
WETLAND STAKEHOLDERS

Stakeholder	Purpose
Direct extensive user	Directly harvests wetland goods in a sustainable way
Direct intensive user	Has access to new technologies that allows to harvest more intensively
Direct exploiters	Dredge sediments in the wetland, or exploit mineral resources, clay, peat and sand without a direct concern for the health of the environment.
Agricultural producers	Drain and convert wetlands to agricultural land
Water abstractors	Use wetlands as sources of drinking water, agricultural irrigation, flow augmentation, and so on.
Human settlements close to wetlands	Wetlands as sites for human settlement expansions
Indirec users	Benefit from indirect wetland services, such as storm abatement and flood mitigation
Non-users	Users that may attribute an intrinsic value to wetlands
Nature conservation and amenity groups	Groups whose objective is to conserve nature and groups who enjoy the presence of plant and animal species

Source: [86]

In most instances, the different interests of these stakeholder's result in conflicts, so that policy-makers are faced with complex trade-offs [86].

Water management in wetlands has often been oriented solely towards the needs of humans, such as transportation, agriculture, flood control and settlement. Instead of an integrated approach towards water management issues, in which the ecosystem and its different stakeholders play a key role, wetlands have been transformed into a wide variety of human uses. In this respect, several engineering techniques have been applied [82]:

- First of all, for the purpose of embankment and water retention, people may construct dykes, dams and reservoirs in rivers that feed wetlands. These may prevent flooding, promote water storage for drinking water or irrigation, or produce electricity.
- Secondly, lakes, rivers or canals in wetlands may be subject to dredging, excavation and deepening, to prevent flooding or, for example, to eliminate shallow water bodies favourable for water-related diseases.
- Third, canalization of waters in wetlands is aimed at the improvement of flows within a river basin or to transfer water to an area where water demand is high.
- A fourth activity that affects wetlands is drainage. Drainage of polders or fields is carried out through, for example, pumping or gravity drainage. The activity may also be carried out to create new land for agricultural, industrial or urban purposes.
- Fifth, in the field of water supply, activities such as exploitation of surface water and groundwater through for example pumping or excavation may be distinguished.
- Lastly, different types of irrigation schemes and techniques require total water control and therefore may have serious adverse effects on wetlands. The results of human interventions can alter the functioning and natural evolution of a wetland, thereby eliminating its potential benefits.

4.10 Threats to Wetland Biodiversity and Future Prospects:

The case study on Djoudj National Bird Park, for example, records the construction of dykes and dams on the upper parts of the Senegal River for the development of rice cultivation [88]. This has altered the freshwater regime, threatening the survival of some plant species and encouraging the spread of others - essentially altering the characteristics of the ecosystem [88]. Equally, the damming of the Tana and Athi rivers in Kenya has blocked upstream movement of migratory fish species, while poor water management schemes in the north of Cameroon have reduced natural flooding in Waza National Park, thus contributing to the decrease in the populations of two species of antelope, the Korrigum Damaliscus *lunatus korrigum* and Buffon's Kob Kobus *kob kob* [83].

More threats to African wetlands are brought up by the changes in the wetland water quality created by industrial effluent and agricultural pesticides, siltation from highland catchment areas, and the unwise introduction of alien species of flora and fauna leading to colonization by single species and loss of endemic species diversity [1]. A good example is the biggest single catastrophe of the introduction of the Nile Perch *Lates niloticus* and a species of tilapia *Oreochromis niloticus* to Lake Victoria which has led to the extinction of a large number of the 200 or so endemic cichlids of the lake; indeed a tragic loss of biodiversity [83]. On the flora side it was the introduction to the same lake of alien plant species, the Water Hyacinth, *Eichhornia crassipes* and Water Lettuce *Pistia stratiotes*, that now threatens the existence of endemic flora [83].

The survival of African wetlands lies in a stronger political will, by the inhabitants, to protect them, based on sound wetland policies and encouragement for community participation in their management [31]. Although the goal for protected wetlands should continue to be conservation of endangered and fragile sites, greater efforts should be focused on wetlands outside protected areas, and new management strategies formulated which incorporate the stakeholders [37]. The Government of Uganda has recently launched such a policy for the conservation of its wetland resources [2]. This is the first of its kind in Africa to have been formulated in accordance with the recommendation from the Ramsar Convention [2]. It encompasses wetlands in protected and non-protected areas and offers the best example in Africa of a strong political will to conserve wetlands and their biodiversity [2]. It is important that African countries put such policies in place, and other management strategies such as Integrated Coastal Zone Planning, an important measure for safeguarding coastal wetlands [33]. Such a plan is being carried out in Guinea Bissau with the assistance of the World Conservation Union (International Union for Conservation of Nature [IUCN]) [42].

Following the framework provided by the Ramsar Convention for supporting conservation and wise use of wetlands, more African states are joining the Convention and designating additional sites for inclusion in the List of Wetlands of International Importance [93]. Other non-members are adopting the Convention's approaches to wetland conservation (especially as regards to development of wetland policy instruments) and taking the necessary steps leading to membership [83]. The growth of the Convention in Africa is an indication of commitment to the conservation and wise use of wetlands and their biodiversity.

4.11 Policy issues and Monitoring Wetlands in Africa:

Management and monitoring of wetlands in Africa remains a serious ecological requirement of all times. This is a direct outcome of poor governance, rhetoric ineffective policies, lack of coordination, poor community engagement practices inter alia. On top of the aforementioned aspects, as populations in Africa are growing, pressures on wetlands are likely to increase hence their extinction [79]. As postulated by the Ramsar Bureau, the future of African wetlands lies in a stronger political or governmental will to protect them, based on sound wetland policies and encouragement for community participation in their management [74].

According to [71], following the framework (to be reviewed) stipulated by the Ramsar Convention for conservation support and sensible use of wetlands, more African states are joining the Convention and designating additional sites for inclusion in the List of Wetlands of International Importance. Non-members to the Convention are implementing the Convention's methodologies to wetland conservation (especially as regards development of wetland policy instruments) and taking the necessary steps leading to membership [94]. The increasing membership in Africa of the Convention is a positive indication of commitment to the conservation and wise use of wetlands and their biodiversity.

Africa joined the rest of the world on an important event for sustainable management of wetlands in 1975. This was when the Convention on Wetlands of International Importance entered into force [86]. But however implementation on local level became another problem altogether. African governments are often characterised by poor governance. This element spills over to environmental management. Usually there is lack of clear-cut structures in environment management institutions. Deconcentration, devolution and decentralisation of powers remain a serious threat to sound policy implementation. The [77] states that, if management is to be effective, issues to strategy adaptation should involve alterations in the system as well as technological and institutional changes that can deal with environmental changes.

African governments, environmental management institutions down to traditional leadership do acknowledge the need to protect wetlands. For some, however, the problem comes from putting policy into practice. Many of the written policies become more rhetoric than substance if not mere fallacy. The lack of foresight in development, inappropriate land use practices and poor land management have significantly impacted wetlands existence in Africa. According to [86] the land and water of wetlands in Africa and elsewhere have been converted to other uses such as agriculture and infrastructure. As stated by [86] reasons for wetlands losses are associated with policy intervention failures due to a lack of consistency among government policies in different areas, including economics, environment, nature protection, physical planning and deficient understanding of the functions and values of wetlands.

Despite the existence of policy frameworks for wetlands protection in Africa there seems to be no synchrony between what is ‘on paper’ and what is in ‘practice’. Usually no proper Environmental Impact Assessments (EIA) are carried out for major construction projects, housing and even agricultural endeavours [77]. The monetary value of projects is considered and preferred over its negative impacts to the environment, especially on most wetlands. According to the [41] the bond attaching people and wetlands must be pivotal to wetland policies and management approaches but the governance of wetlands can be highly political. In Zimbabwe, Monavel wetlands is one good example where policy was overridden by political power. The Chinese, because of their ‘political relationship’ with the government, were granted permission to build the Long-Cheng Plaza on the Monavel wetlands. The main drivers of wetland degradation, regionally, were found to be weak policy, poor law enforcement, inappropriate governance and limited consideration of wetlands in national and local land-use planning and development agendas [78].

The National Wetlands Programme of Uganda was established in 1989 to assist the government to develop national policy for the conservation and management of wetlands and to seek alternatives to their unsustainable use and abuse. The Government of Uganda has recently launched such a policy for the conservation of its wetland resources [76]. As mentioned earlier, this is unique in Africa to have been formulated in accordance with the recommendation from the Ramsar Convention. It involves looking at wetlands in both protected and non-protected areas and offers the best example in Africa of a strong political will to safeguard wetlands and their biodiversity [76]. It is important that African countries put such policies in place, and other management strategies such as Integrated Coastal Zone Planning, an important measure for safeguarding coastal wetlands [79]. Presently this plan is being implemented in Guinea Bissau with the assistance of the World Conservation Union (IUCN) [79].

4.12 Rehabilitation/Restoration of Wetlands in Africa:

As stated, earlier on, wetlands are known to harbour significant bio-diversity [80] and supply crucial ecosystem services [70]; [80], which were defined as the benefits that people obtain from the ecosystems [74]. The ecosystems provided by wetlands include regulating water purification, protecting the ecosystem from soil erosion and effects of flooding, and nursing the early growth of many species essential to oceanic fisheries. Although wetlands occupy less than 9% of the Earth’s terrestrial surface, they contribute up to 40% of global annual renewable ecosystem [81]. Despite their importance to human societies, wetlands are rapidly being degraded and destroyed [81], threatening the ecosystem and biodiversity on which wetland ecosystems depend.

In order to offset for their extensive degradation, wetland restoration and rehabilitation has become common practice around the world. It has been reported, via many studies, that restoration can recover much of the biodiversity and ecosystems lost due to degradation [82]. But other studies have been sceptical about this and have called into question the effectiveness of wetland restoration, suggesting that its positive impacts depend strongly on factors such as ecosystem type and restoration actions [81]. For example, some authors have suggested that current wetland restoration methods are too slow and incomplete to allow recovery of biological structure and biochemical function [83]. Therefore, the effectiveness of wetland restoration remains controversial, and this is in part because different studies have applied different standards to evaluate outcomes [84]. At the same time, most studies evaluating wetland restoration including a recent meta-analysis [79] have not directly assessed ecosystem recovery or how well restoration methods work for diverse types of organism.

The salvaging of biodiversity and ecosystems can be regarded as distinct goals of wetland restoration, with a given restoration effort focusing on one or the other [82]. However, gauging the attainment of both types of recovery simultaneously is important for several reasons. Biodiversity and ecosystems of restored wetland often do not reach pre-degradation levels or the levels of similar natural ecosystems, and recovery of biodiversity may correlate with recovery of ecosystems [85]; [86]. Indeed, recovery of biodiversity may be a prerequisite for recovery of ecosystems [83], for instance increasing biodiversity enhances key ecosystems such as primary productivity [87] and soil erosion control [88]. This comparable recovery of biodiversity and ecosystem may indicate a win-win outcome for ecosystem and society alike. Additionally, assessments of wetland restoration should consider the context in which the restoration occurs, since restoration effectiveness may strongly depend on the type of ecosystem being restored, its pre-restoration condition, and the factors responsible for its degradation [82]. By analysing wetland restoration simultaneously in terms of biodiversity and ecosystems, we can identify factors that affect the recovery of either or both, allowing us to develop recommendations for researchers and practitioners.

In their meta-analysis of seventy studies carried out in fourteen countries indicated that wetland restoration increased biodiversity in degraded wetlands, consistent with another global meta-analysis different ecosystem types [86]. It was confirmed that restoration increased the biodiversity of native organisms to level similar to those in natural wetlands [82]. In some cases vertebrate diversity was improved during restoration to levels above those in natural wetlands, though this result may only be transient, since vertebrate richness can vary substantially over time [89]. But on the contrary, restoration led to levels of biodiversity of non-native vascular plants lower than levels in natural wetlands [82]. Both of these outcomes may reflect the large, persistent effects of exotic plants on the habitats structure biodiversity and function of wetlands [81]. In addition, wetlands dominated by exotic invasive plants tend to support fewer native animal species and more invasive animals [81]

Repercussions for wetland restoration comparing degraded and restored and reference conditions to guide restoration may not be feasible in many cases because the no-reversibility of much of man-made ecosystem damage makes it difficult to kindle the pre-degradation condition accurately [90] and because movement of restored wetlands away from reference conditions makes it difficult to project desired outcomes [83], but it should be advisable. This emphasises and underlines the need for planning restoration programmes with multiple alternative goals in mind [90]; [91]. These goals should take cognisant of the social context and human values associated with decisions about wetland management and restoration [82].

Many schemes have been taken to help stop or avoid the destruction of wetlands and several programmes have been crafted to help restore them. The most significant of these schemes is the Ramsar Convention on Wetlands [41]. Recently one of the key aspects that the Ramsar Convention advocates is the principle of 'wise use' [41]. With human activities proving to be the most dangerous threat to wetlands, Africa needs to work on rehabilitating its rich wetland ecosystems. In Africa, since millions of people directly depend on wetlands for their livelihood, policy makers should consider full engagement of the local communities in their management practices. Although, when using the people centered approach, conflicts and trade-offs between livelihood requirements and conservation are common, these require skilful and innovative forms of management [82].

4.13 The Benefits of Restoring Degraded Wetlands:

The definition of restoration, in its broadest sense, by the Ramsar Convention is the activities that promote a return to previous condition as well as those that improve the function of a wetland without necessarily seeking to return it to its pre-disturbance condition [92]. This concept of restoration comes from the cited definition of ecological restoration as the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed [140]. The attributes of successful wetland restoration activities include:

1) the utilization of native wetland species in characteristic assemblages and functional groups,
2) self-sustaining and resilient wetland ecosystems integrated within the larger landscape and
3) the reduction or elimination of the drivers of wetland degradation [93].

In 2002, the Ramsar Convention adopted principles and guidelines from wetland restoration to assist decision-makers and wetland managers [92].

The restoration of lost or degradation of wetlands signifies a valuable and cost-effective opening for society to salvage and enhance benefits for human health and well-being, including reduced risk from storms and other extreme events, improved food and nutrition and water security, and capacity to mitigate and adapt to climate change [94]. The restoration of mangroves and near-shore habitats, for example, provides food (fish and invertebrates) and other basic necessities, habitat for birds, reptiles and mammals, carbon appropriation and climate protection and it adds to enhanced socio-economic strength among coastal communities [95]. The accumulated worthiness of benefits that flow from a rejuvenated wetland can often be several times higher than the cost of restoration when added to the value of the benefits lost due to degradation [2]. As nature characteristically provides ecosystem services at a lower cost than human-made systems, wetland restoration can be a cost-effective, long-term strategy for achieving conservation and development objectives simultaneously [95].

It is a proven fact that restoration is able to clearly play an important role in enhancing existing and recovering lost benefits, but to date experience shows that a restored wetland rarely provides the full range and magnitude of services delivered by a wetland that has not been degraded [83]. Thus, the first priority should be to conserve and sustainably use wetlands rather than allow for their continued degradation [95].

It should be noted that wetland restoration will benefit a multiple of sectors, concurrently, for example, agriculture, fisheries, water, forestry, health, energy, extractive industries, recreation, transport, education, development and indigenous and local communities. Restoration is a national decision-making process and is needed to counteract the loss and degradation of wetland ecosystems and their benefits in many countries [94]. The following examples illustrate opportunities for wetland restoration that assist in delivery on a range of objectives beyond simply the recovery of biodiversity [93]:

Included in the failure to appreciate the existence and value of certain ecosystem services, there are various reasons why wetland values are not considered properly or fully in decision-making, these include [95]:

- Market failures where many wetland benefits are considered public goods provided for free by a wetland ecosystem, or so-called externalities when the market does not truly reflect the social costs or benefits of a change in the delivery of an ecosystem service
- Perverse incentives where policies or subsidies provide the inducement for economic activity which unintentionally impedes wetland restoration or further degrades wetlands
- Unequal distribution of costs and benefits where the stakeholders who benefit from the ecosystem services are not the same as the stakeholders who bear the cost of maintaining the benefit
- No clear ownership or tenure as indicated by clear boundaries, thus making the allocation of benefits to define

4.14 Current Situations and Future Prospects:

The Ramsar Convention has put forward the following recommendations to improve the understanding and protection of wetlands in the world, which Africa can adopt to safeguard its own wetlands [102]:

- Enhance the network of Ramsar sites and other wetland protected areas. Management and policy plans must be developed and implemented for effectiveness.
- Integrate wetlands into planning and implementation of the post 2015 development agenda.
- Strengthen legal and policy arrangements to protect all wetlands.
- Implement Ramsar guidance to achieve wise use.
- Apply economic and financial incentives for communities and businesses.
- Integrate diverse perspectives into wetland management. Multiple wetland values must be considered.
- Improve national wetland inventories and track wetland extent (monitoring).
- Restoration to be implemented without delay, always.
- Securing source of funding for wetland conversation and restoration is a precondition to achieve success.

V. RECOMMENDATIONS

Subsequent to the framework provision by the Ramsar Convention for supporting conservation and wise use of wetlands, more African states have joined the Convention and designating additional sites for inclusion in the List of Wetlands of International Importance. Non-members are adopting the Convention’s approaches to wetland conservation (especially as regards development of wetland policy instruments and taking the necessary steps leading to membership). The growth of the Convention in Africa is an indication and wise use of wetlands and their biodiversity. Over the past forty years wetland conservation and restoration in developed countries has been progressing well, but many developing regions have no regulations or restrictions to control the continuous destructions and pollution of wetlands [3].

VI. CONCLUSION

The review study has concluded that, even if, restoration or rehabilitation can noticeably play an important role in augmenting existing and recovering lost benefits, facts indicate that a restored wetland rarely provides the full range and magnitude of services delivered by a wetland that has not been degraded.

Even if each continent has a certain number of wetlands signed with the Ramsar Convention, the total area of these wetlands accounts for less than 19% of global wetlands. The Ramsar Convention is still calling for more wetlands around the world to join in order to save more wetlands.

The most seriously impacted regions are mainly located along the coasts, major inland rivers and lakes of Oceania and Africa. Sites affected by climate change and extreme weather are mainly marine/coastal wetlands and marsh wetlands, mainly located in the southeast area of Oceania and the northwest area of Africa.

The majority of river wetlands are at risk to the land occupation, environmental pollution, species invasion and excessive regulation of water resources which may be related to people's preference for living near rivers since ancient times, lake wetlands are vulnerable to land occupation and climate change, which may be due to the geographical environment of the lake and precipitation as the main source of the water supply of lakes. Biological resources of marsh wetlands have attracted over-exploitation by human beings. Marine coastal wetlands are most affected by pollution and climate change, which may be due to the economic development of coastal cities and sea level rise caused by climate warming.

According to the level classification results, wetland sites both containing natural wetlands and human-made wetlands are susceptible to a multiple factors. We can generally draw conclusion that wetlands artificially reconstructed are more vulnerable [101].

The meta-analysis by [82] indicated that ecological restoration improves both biodiversity and ecosystem supply in degraded wetlands, thereby benefiting the human communities that interact with and depend on them. The detailed effects of restoration depend heavily on context factors, emphasizing the need for habitat-specific planning and assessment of restorations [84]. Questions posed on wetlands over the years remain unanswered such as "to what extent can mankind substitute for ecosystem?" [102] and "to what extent and over what time scale can ecosystem be restored?".

While restoration ecology is not necessarily going to respond to these questions, further investigation/research on them may help improve the flows of ecosystem and improve human well-being [82]. Answering these questions will indeed entail deepening our understanding of the links between restoration actions and changes in biophysical and ecological processes that generate ecosystem [103]. It is still not clear that such research could enlighten and expand growing efforts to restore and lessen the loss of wetland area and loss of ecosystem functions [104]. This must not take the importance away from efforts to conserve natural wetlands and avoid environmental degradation in the first place [85] ; [86].

Therefore millions of people, plants and animals who survive by exploiting natural resources of wetlands do face a grim future and unfortunately will perish.

As mentioned earlier wetland management plans in each continent are not perfect especially in Africa and Asia. It is imperative for local, national, regional and international cooperation to work together continually to strengthen global wetlands conservation and restoration so that the implementation of the wetland management plans maybe more effective. This can be carried out under the following subheadings (1) management and policy, (2) monitoring, (3) restoration, (4) knowledge, and (5) funding (see Table 14 above)

ETHICS

Human and Animal Rights:

No animals/humans were used for studies that are base of this research

Consent for Publication:

Not applicable

CONFLICT OF INTEREST

The author (Douglas Ncube, PhD) certify that he has no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria, educational grants; participation in speakers' bureaux; membership; employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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Development and Evaluation of High Yielding, Multiple Disease Resistant Bread Wheat Variety – GW 513

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Abstract— *Central zone is the third largest wheat producing zone of India which occupies 23.15% of total area and accounts for 20.37% of the total production of wheat in the country. For sustaining the high productivity levels in these areas, a constant demand of improved wheat varieties from the wheat breeding programs is desired. A high yielding bread wheat cultivar GW 513 has been developed and released for cultivation in these areas after testing in trials under AICRP on Wheat and Barley. GW 513 is a high yielding wheat genotype which has shown a significant yield superiority under timely sown irrigated conditions of Central zone over the checks GW 322 and HI 1544 during 2018-19 & 2019-20. Average yield of GW 513 during three years of testing was recorded to be 58.5 qha^{-1}. It has a potential yield of 77.4 q/ha at Tikamgarh location during 2019-20. The variety was released by Central Sub-committee on Crop Standards, Notification and Release of variety, Ministry of Agriculture, Government of India vide notification No. S.O. 8(E) dated on 24th December, 2021 for cultivation in the central zone of India. GW 513 is having a high yield potential along with disease resistance and superior grain quality. The ability to adopt across variable growing conditions in central zone is a huge advantage for this genotype and will also go a long way in sustaining its cultivation in the region*.

Keywords*— *GW 513, central zone, high yield potential, rust resistance, wheat.

I. INTRODUCTION

Bread wheat (*Triticum aestivum* L., 2n = 6x = 42, AABBDD) is staple food of 35% of the world's population and provides ~20% of the protein consumed by humans (Shifrew *et al.*, 2013). To meet the growing demand of wheat with shrinking acreage, has been a challenge to sustain wheat production. Estimates are that to feed the increased human population of about 9 billion by 2050, wheat production will need to be increased by more than 60%, which is a huge challenge considering the changing global climate and reducing arable land (Muller *et al.*, 2018). Genetic improvements in wheat play a crucial role in enhancing crop productivity and in meeting the current and future food security requirements. Breeders throughout the world including India have succeeded in achieving significant gain in productivity (Rajaram and van Ginkel, 1996).

The All India Coordinated Wheat Improvement Project (AICWIP) was started in 1965 is one of the largest crop improvement network projects which set the dawn for the 'Green Revolution' in India. Indian wheat area is divided into five agro-climatic zones due to diverse production environments *viz.*, Northern Hills Zone (NHZ), North Western Plains Zone (NWPZ), North Eastern Plains Zone (NEPZ), Central Zone (CZ) and Peninsular Zone (PZ).

Under this project, several high-yielding wheat varieties have been developed which became extensively popular and adopted by the farming community. For instance, C 306, HD 2009, WL 711, UP 262, HUW 234, HD 2189, WH 147, Lok 1, HI 617 (Sujata), HD 2285, HD 2329, PBW 343, Raj 3765, PBW 502, HD 2733, HD 2967, HD 3086, DBW 17, PBW 550, GW 273, GW 322, GW 496, HD 2967, HD 3086, DBW 187 and WB 2 in bread wheat were developed and became the popular deliverables of the project. Apart from the aforementioned varieties, *viz.*, NP 4, Kalyansona, Sonalika, Sharbati Sonora, WL 711, HD 1220, HD 1931 'SIB', HD 2009, HD 2172, UP 262, etc., developed through the AICWIP were also cultivated beyond national borders. (Sharma *et. al*., 2014)

The Central Zone comprises Madhya Pradesh, Chhattisgarh, Gujarat, Rajasthan (Kota and Udaipur divisions) and Uttar Pradesh (Jhansi division). In CZ wheat is cultivated in around 6.84 million ha area and estimated production was 22.37 mt with productivity of 2978 kg/ha and this zone is also having sizeable area under durum wheat. CZ is the third largest wheat producing zone of India which occupies 23.15% of total area and accounts for 20.37% of the total production of wheat in the country. In Central Zone of India, the major constraints are characterized by the non-availability of labour, imbalanced use of fertilizer, high temperature at maturity, limited accessibility to seed of newly released variety, temperature fluctuation during crop growth, high cost of inputs, lack of irrigation facilities, small land holding, decline in water table, untimely rain limit the wheat productivity. The CZ of wheat is known for premium quality bread wheat having typically hard lustrous grains with high gluten strength. Thus the need to focus research on new emerging issues like change in the dynamics of diseases and pests under changing climatic condition as well as improvement in quality traits of wheat in Central Zone of India. Development and evaluation of disease resistant wheat lines has contributed in successful implementation of breeding goals across wheat improvement programs in the country (Kumar *et al*., 2014, Yadav *et al*., 2017). In CZ, Lok 1 was the most preferred wheat variety by the farmers of this zone till 2005 developed by Lokbharti Gramvidyapith. Three varieties *viz.*, GW 322, GW 366 & HI 1544 under timely-sown condition harvested the wheat yield up to 51.2 q/ha. Of late Lok 1 has become susceptible to black and brown rust of wheat. In this perspective, a new wheat genotype GW 513 has recently been developed and released for cultivation in central zone (Gupta *et al*., 2023).

II. MATERIALS AND METHODS

Hybridization was made using the parents PBW 559 and WR 1873 in the year 2008-09 followed by pedigree method of selection. Single plant selection was made in the year 2009-10 and was advanced in further generations. Rust disease was monitored in the segregating generations using susceptible varieties in the border lines which were also inoculated artificially. It was found suitable for timely sown condition so from bulk population it was promoted to preliminary evaluation trial at 3 locations during 2016-17. Further it was tested in small scale varietal trial in the year 2017-18 at 5 locations; simultaneously it was screened for black and brown rust in the IPPSN under artificial inoculations under AICRP approach. Figure 1 depicts flow chart of details of development and evaluation of GW 513 in coordinated trials. In 2018-19 the entry was promoted and evaluated in national trial NIVT-2 as GW 513 at 9 locations in CZ. The genotype was promoted to AVT-IR-TS-CZ and was evaluated in 12 rows of six metre spaced at 20 cm with four replications in randomized complete block design at 18 and 14 locations during 2019-20 and 2020-21 respectively. Rust severity and response in the field was scored following Loegering (1959) 0-100 scale. For statistical analysis the rust reactions were converted into a coefficient of infection (COI) as used by Loegering (1959). Gene postulation for rust resistance genes was done after multipathotype testing at seedling stage scoring 0-4 scale of Stakman (1962). PPVFRA guideline for the conduct of test for Distinctiveness, Uniformity and Stability (DUS) on wheat (*Triticum aestivum* L.) was followed for characterization of GW 513.

Flow chart of details of development of Bread wheat variety GW 513:

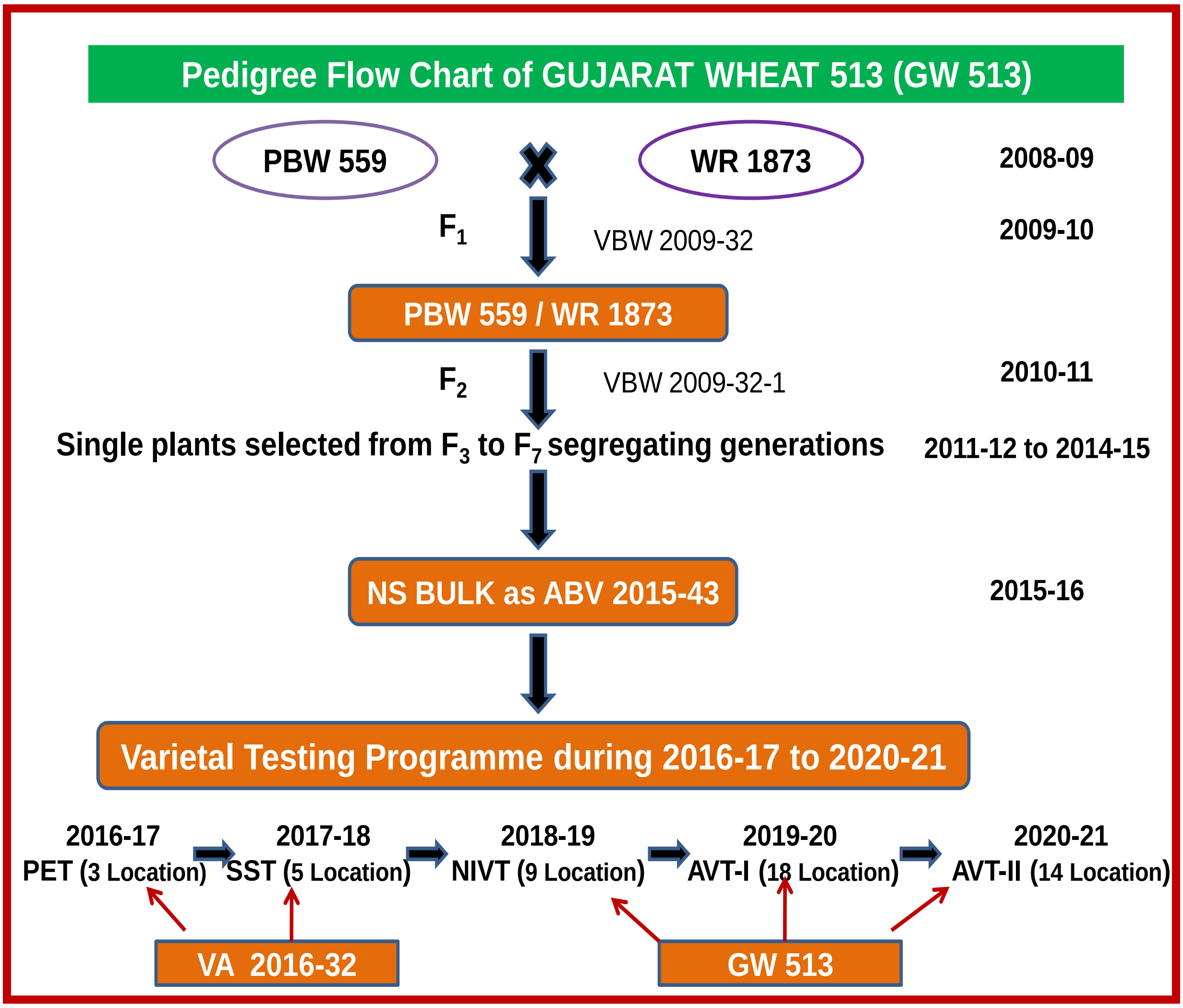

FIGURE 1: Flow chart of details of development of bread wheat variety GW 513

III. RESULT AND DISCUSSION

3.1 Yield evaluation in CZ trials:

The performance of GW 513 was assessed in preliminary evaluation trial at three locations during 2016-17 and small scale trial at five locations during 2017-18 wherein this line was tested as VA 2016-32. It was ranked first with an average yield of 51.0 qha^{-1}. Based upon its superiority over checks the genotype along with other test entries and check varieties were evaluated for three years i.e. 2018-19 (NIVT-2), 2019-20 (AVT-IR-TS-TAS-CZ) and 2020-21 (AVT-IR TS-TAS-CZ) under All India Coordinated Wheat Improvement Program (AICWIP). GW 513 showed a superior and stable yielding ability under timely sown conditions at various locations of central zone India over the three years (2018-19 to 2020-21) in the coordinated trials as compared to all the checks GW 322 and HI 1544 (Table 1). It has yield advantage of 5.0 & 4.5% over the checks GW 322 and HI 1544 respectively over three years of testing. The frequency of occurrence of GW 513 in the top non-significant group was highest amongst all test entries and checks. It was 21/41in top non-significant group on overall basis of 3 years as compared to GW 322 (15/41) and HI 1544 (15/41) (ICAR-IIWBR 2021a, ICAR-IIWBR 2020a, ICAR-IIWBR 2019). The yield potential of GW 513 under AVT was as high as 77.4 qha^{-1} at Tikamgarh location during 2019-20 (Table 1).

TABLE 1
PERFORMANCE GW 513 OVER CHECKS FOR GRAIN YIELD UNDER COORDINATED TRIALS IN CZ FROM 2018-19 TO 2020-21

Particulars	Year of testing	Trials	Proposed variety	Check varieties		CD (10%)
			GW 513	GW 322	HI 1544	
Yield (q/ha)	2018-19 (NIVT-2-IR-TS-TAS-CZ)	**9**	60.1*	56.0	55.5	**2.8**
	2019-20 (AVT-IR-TS-TAD-CZ)	**18**	62.0*	57.4	58.8	**1.1**
	2020-21 (AVT-IR-TS-TAD-CZ)	**14**	53.0	53.4	52.8	**1.1**
	Weighted Mean	**58.5**	**55.7**	**56.0**	**-**	
% Increase / decrease over checks & qualifying variety	2018-19 (NIVT-2-IR-TS-TAS-CZ)	-	7.3	8.3		
	2019-20 (AVT-IR-TS-TAD-CZ)	-	8.0	5.4		
	2020-21 (AVT-IR-TS-TAD-CZ)	-	-0.7	0.4		
	Weighted mean	**-**	**5.0**	**4.5**		
Frequency in 1st NS group	2018-19 (NIVT-2-IR-TS-TAS-CZ)	*5/9*	*3/9*	*3/9*	-	
	2019-20 (AVT-IR-TS-TAD-CZ)	*10/18*	*7/18*	*8/18*	-	
	2020-21 (AVT-IR-TS-TAD-CZ)	*6/14*	*5/14*	*4/14*	-	
	Total	***21/41***	***15/41***	***15/41***		

3.2 Disease Resistance:

GW 513 showed resistance against brown and black rust in NIVT- 2, AVT I and II during 2018-19 to 2020-21 under All India coordinated breeding trials (natural) and artificial epiphytotic in Plant Pathological Screening Nurseries (PPSN). GW 513 is resistant to important and prevalent pathotypes of brown and black rusts (ICAR-IIWBR, 2020b; ICAR-IIWBR, 2021b). Resistance gene R+Lr24+ (brown rust resistance) and Sr24+ (black rust resistance) have been postulated in this variety through multipathotype testing for seedling resistance (Table 2). It also showed high level of adult plant resistance (Table 3) to brown rust (ACI 4.0) and black rust (ACI 3.3). GW 513 showed better resistance (6.1%) against Karnal bunt as compared with check variety HI 1544 (16.7%) whereas, for Powdery mildew, flag smut and foot rot it showed at par reaction than the check variety GW 322 (Table 4).

TABLE 2
GENE POSTULATION FOR RUST RESISTANCE BASED ON MULTIPATHOTYPE TESTING (2019-20 & 2020-21)

Disease	Proposed variety		Check Varieties			
	GW 513		GW 322		HI 1544	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Black Rust	*Sr24+*	*Sr24+*	*Sr11+ 2+*	*Sr11+ 2+*	*Sr24+ 2+R*	*Sr24+ 2+*
Brown Rust	*Lr24+*	*R+ Lr24+*	*Lr13+1+*	*Lr13+1+*	*Lr24+*	*R+ Lr24+*

TABLE 3
REACTION TO RUST DISEASES IN NATURAL AND ARTIFICIAL EPIPHYTOTIC CONDITIONS

Disease	Year	Proposed variety		Check Varieties			
		GW 513		GW 322		HI 1544	
		HS	ACI	HS	ACI	HS	ACI
Leaf Rust							
Natural condition	2018-19	0	-	TR	-	0	-
	2019-20	0	-	5MR	-	0	-
	2020-21	-	-	-	-	-	-
Artificial condition	2018-19	TR	0.0	60S*	9.3	TR	0.1
	2019-20	60S	8.8	80S	14.6	40S	5.1
	2020-21	20S	3.2	20MS	7.3	40MS	5.8
	Highest Score & Mean ACI	**60S**	**4.0**	**80S**	**10.4**	**40S**	**3.7**
Stem Rust							
Natural condition	2018-19	0	-	TS	-	TR	-
	2019-20	0	-	5MS	-	TR	-
	2020-21	-	-	-	-	-	-
Artificial condition	2018-19	20S	4.3	40S*	11.7	20S	4.0
	2019-20	5MS	2.3	40S	15.8	10S	2.8
	2020-21	10MS	3.3	30S	8.3	30S	5.3
	Highest Score & Mean ACI	**20S**	**3.3**	**40S**	**11.9**	**30S**	**4.0**

HS = Highest score, ACI = Average coefficient of infection

TABLE 4
REACTION TO OTHER DISEASES

Disease	Year	Proposed variety		Check Varieties			
		GW 513		GW 322		HI 1544	
		HS	Av	HS	Av	HS	Av
Karnal Bunt (%)	2019-20	14.3	5.6	15.0	5.0	42.9	11.6
	2020-21	12.5	6.5	8.5	4.8	64.5	21.8
	Mean	13.4	6.1	11.8	4.9	53.7	16.7
Leaf Blight (dd)	2019-20	89	56	89	45	89	57
	2020-21	99	57	79	46	99	56
	Mean	94	57	84	46	94	57
FHB or Head Scab (0-5)	2019-20	5	-	4	-	4	-
	2020-21	5	-	5	-	4	-
	Mean	5	-	5	-	4	-
Powdery Mildew (0-9)	2019-20	9	5	9	4	9	4
	2020-21	9	5	9	6	9	4
	Mean	9	5	9	5	9	4
Flag Smut (%)	2019-20	11.1	3.7	7.5	4.6	23.1	12.2
	2020-21	20.0	12.4	9.7	8.6	33.9	21.4
	Mean	15.6	8.1	8.6	6.6	28.5	16.8
Foot Rot (%)	2019-20	10.0	-	0.0	-	18.8	-
	2020-21	68.8	-	35.0	-	70.0	-
	Mean	39.4	-	35.0	-	44.4	-

HS= Highest score, Av= Average score

3.3 Quality traits analysis:

The quality analysis showed that GW 513 is having a good chapati-making score (8.36/10.0), high bread loaf volume (517 cc) and excellent quality of protein with a perfect Glu score of 8.0 (Table 5). Glu-D1 subunits of high molecular weight gluten (HMW) were found to be 5+10 for GW 513. The protein content was found to be 10.7%. The higher sedimentation value of 41.0 ml in GW 513 reflects its strong gluten and hence better bread making quality (ICAR IIWBR, 2021c). Biscuit spread factor was found to be 6.8 whereas; grain hardness index was 69.0 in the variety. Wet gluten and dry gluten content was found to be 34.7% and 10.7% respectively whereas, gluten index and phenol score was 57 and 4.1/10.0 in this variety respectively.

TABLE 5
PERFORMANCE OF GW 513 ALONG WITH CHECKS FOR QUALITY TRAITS UNDER COORDINATED TESTING

Quality Characteristics	Proposed variety	Check Varieties	
	GW 513	**GW 322**	**HI 1544**
Grain characteristics			
Protein (%)	10.7	10.6	11.4
Grain appearance score (Max score 10)	7.0	6.6	6.9
Hectoliter weight (kg/hl)	81.7	79.5	82.0
Sedimentation value (ml)	41.0	41.0	44.0
Grain hardness index	69	81	75
High Molecular Weight Glutenin Subunits (HMW-GS)			
GLu-D1	5 + 10	2 + 12	2 + 12
GLu-A1	N	2*	N
GLu-B1	17 + 18	7 + 8	7 + 8
Score	**8**	**8**	**6**
***Chapati*, bread and biscuit quality**			
Wet Gluten (%)	34.7	33.5	33.9
Dry Gluten (%)	10.7	10.3	10.5
Gluten Index (max 100)	57	45	48
Bread quality loaf volume (cc)	517	511	505
Bread quality score (max 10)	5.38	5.30	5.09
Chapati quality score (max 10)	8.36	7.83	7.81
Biscuit quality (Spread Factor)	6.8	6.7	6.8
Phenol Test (Max. Score 10)	4.1	7.1	7.3

3.4 Performance of GW 513 for agro-morphologic traits:

The new variety GW 513 exhibited an average plant height of 96 cm in the co-ordinated trial. It recorded mean days to heading and maturity 66 and 119 days, respectively and high thousand grain weight (47g). Oblong grain shape, pubescence on outer glume, medium brush hair and weak waxiness on spike are the distinct traits of GW 513 under DUS criteria. (Table 6).

TABLE 6
PERFORMANCE OF GW 513 FOR AGRO-MORPHOGICAL AND PHENOLOGICAL TRAITS IN CZ UNDER COORDINATED TESTING

Traits	GW 513	GW 322	HI 1544
Heading days	66	70	65
Maturity days	119	120	118
Plant height (cm)	96	91	91
1000 grain weight (g.)	47	41	45
Grain shape	Oblong	Ovate	Round
Pubescence on outer glume	Strong	Absent	Medium
Brush hair	Medium	Long	Short
Waxiness on spike	Weak	Medium	Weak

3.5 Notification:

GW 513 was notified for cultivation in CZ vide notification No. S.O. 8(E) dated on 24th December, 2021 cultivation CZ which covers Madhya Pradesh, Chhattisgarh, Gujarat, Kota and Udaipur district of Rajasthan and Jhansi division of Uttar Pradesh.

IV. CONCLUSION

GW 513 is having a high yield potential along with disease resistance and superior grain quality. The ability to adopt across variable growing conditions in central zone is a huge advantage for this genotype and will also go a long way in sustaining its cultivation in the region.

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Treatability Study of Pharmaceutical Wastewater by Hydrodynamic Cavitation Process

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Abstract— *In the present work, degradation of pharmaceutical effluent has been investigated using hydrodynamic cavitation process. In this study, the effect of hydrodynamic cavitation was examined for the different time intervals from 0 to 150 mins. In hydrodynamic cavitation pump was used of 1 H.P capacity and reactor capacity were 50 litres. With hydrodynamic cavitation, the maximum COD removal achieved was 80.36% in 90 mins*.

Keywords— Advanced oxidation process, COD removal, pharmaceutical wastewater, cavitation.

I. INTRODUCTION

The existence of pharmaceutical substances in the aquatic environment and their possible effects on living organisms are a growing concern. The treatment of pharmaceutical wastewater to the desired effluent standards has always been difficult due to the wide variety of the products that are produced in a drug manufacturing plant. Variable wastewater composition and fluctuations in pollutant concentrations cannot be treated by conventional treatment plants. Activated sludge process is a well-for removing various organic contaminants and organic carbon. However, the substances synthesized by pharmaceutical industries are organic chemicals that are structurally complex and resistant to biological degradation. The treatment of pharmaceutical wastewater requires some complementary techniques that could efficiently remove pollutants and enable the wastewater to be discharged into receiving water or be reused for industrial purposes.

Pharmaceutical and antibiotic residues from human, animal and medical waste enter in the water and soil from:

1) The effluent treatment plants of manufacturing facilities,
2) The municipal sewage treatment plant,
3) Hospital waste treatment plants, or 4) Animal farms.

Most pharmaceutical substances are, by nature, biologically active and hydrophilic, in order that the human body can take them up easily, and persistent, to avoid degradation before they have a curing effect. Depending on the pharmacology of a medical substance it will be excreted as a mixture of metabolites, as unchanged substance, or conjugated with an inactivating compound attached to the molecule. When they enter a wastewater treatment plant, xenobiotic is not usually completely mineralized. They are either partially retained in the sludge or metabolized to a more hydrophilic but still persistent form and, therefore, pass through the wastewater-treatment plant and end up in the receiving waters.

II. MATERIAL AND METHODS

Cavitation is described as the formation of micro bubbles in solution that implode violently after reaching a critical resonance size. These micro bubbles can be produced by several mechanisms (**Madhu G M, Rajanandam K S, Thomas A, 2010)**:

1) Local increase in water velocity as in eddies or vortices, or over boundary contours;
2) Rapid vibration of the boundary through sonication;

3) Separation or parting of a liquid column owing to water hammer; or

4) An overall reduction in static pressure.

The rapid implosion of cavitation micro bubbles results in high temperatures at the bubble/water interface, which can trigger thermal decomposition of the toxic elements in solution or thermal dissociation of water molecules to form extremely reactive radicals. The extreme conditions generated during cavitation decomposes water to create both oxidizing (•OH) and reducing (•H) radical (**Gogate P R and Pandit A B, 2000)**.

There are three known methods of producing hydroxyl radicals using cavitation — namely, ultrasonic irradiation or sonication, pulse plasma cavitation, and hydrodynamic cavitation. Sonication causes the formation of micro bubbles through successive ultrasonic frequency cycles until the bubbles reach a critical resonance frequency size that results in their violent collapse. Pulse plasma cavitation utilizes a high voltage discharge through water to create micro bubbles. In hydrodynamic cavitation, micro bubbles are generated using high velocity or pressure gradients (**Gore M M and Chavan P V, 2013)**.

2.1 Factors affecting hydrodynamic cavitation:

Cavitation number, Inlet pressure, Diameter of the constriction, Physicochemical properties of the liquid and the initial size of nuclei, Percentage of free area for the flow (**Chanda S K, 2008)**

Hydrodynamic cavitation has great potential in water disinfection due to its capability to generate highly reactive free radicals and turbulence. The mechanism involved in disinfection of microorganisms by cavitation is thought to involve the following effects **(Gogate and Kabadi, 2009)**.

1) **Mechanical effect:** Associated with the generation of currents, shear stresses and turbulence due to liquid circulation.

2) **Chemical effect:** Generation of free hydroxyl radicals.

3) **Heat effect:** Hot spot generation due to high local pressure and temperature.

It has been observed that in hydrodynamic cavitation, chemical and thermal effects play supporting roles to mechanical effects in microbial disinfection. **(Jyoti and Pandit, 2004)** applied ozone and hydrodynamic cavitation to bore well water and found this technique much more effective in water disinfection compared to other individual physical-chemical techniques including ozonation, hydrodynamic cavitation and acoustic cavitation.

Cavitation can also be used as supplementary technique to a conventional biological oxidation process to increase substrate biodegradability or to reduce toxicity by degrading bio refractory materials **(Gogate and Kabadi, 2009)**. It can also be used with an anaerobic digestion process to improve the digestibility of the sludge by solubilising it.

2.2 Hydrodynamic vs. acoustic cavitation:

Acoustic cavitation in the form of ultrasound has been observed capable of removing a wide variety of contaminants from water. Significant research has been done in this field compared to hydrodynamic cavitation, but most of the studies have been done at laboratory scale. Scale-up is a big issue in acoustic cavitation compared to hydrodynamic cavitation. Designing large scale acoustic cavitation equipment involves information from a variety of fields compared to hydrodynamic cavitation. Hydrodynamic cavitation reactors offer versatility and ease of operation. Several studies have proven that hydrodynamic cavitation is much more energy efficient and effective than acoustic cavitation (Gogate and Pandit, 2005; Gogate and Kabadi, 2009; Jyoti and Pandit, 2004; Kalumuck and Chahine, 2001; Save et al., 1997).

III. EXPERIMENTAL PROCEDURE

For hydrodynamic cavitation, experiments were performed in a reactor of capacity 50 liters in which effluent was lifted and circulated by the pump of capacity 1 H.P. for different intervals of time without using any chemical. The sample was kept for quiescent condition for 2 hours for the settlement of the precipitate. All experiments were carried out in batch mode. Several sets of experiments were carried out to check the optimum range of time.

FIGURE 1: Hydrodynamic Cavitation Reactor

IV. RESULT AND DISCUSSION

TABLE 1
RAW EFFLUENT CHARACTERISTICS

Sr. No.	Characteristics	Values
1	Chemical Oxygen Demand (COD)	8900 – 9500 mg/L
2	pH	7.8 – 8.2
3	TDS	47500 mg/L
4	TSS	8300 mg/L

The wastewater characteristics play a significant role on its treatment. Raw wastewater parameters were measured and listed in Table 1. These results indicate that this wastewater contains high load of organic and inorganic matter. Therefore, this wastewater can cause damage to the environment when discharged directly without proper treatment.

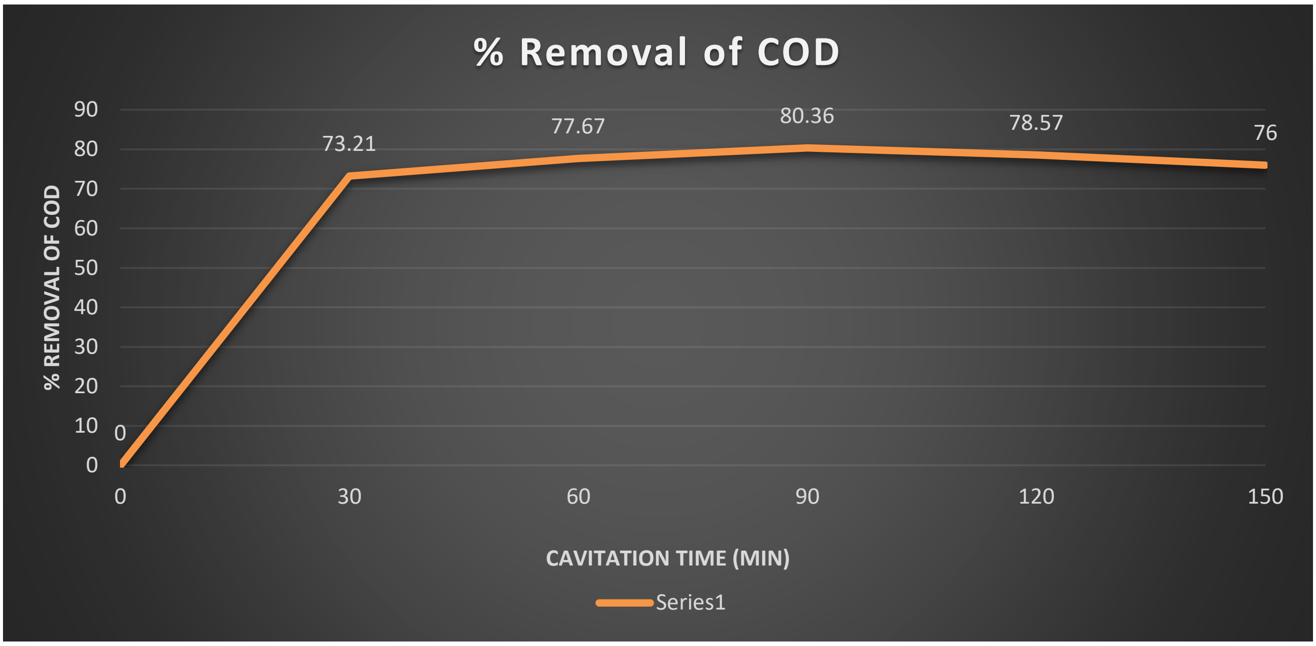

FIGURE 2: % COD Removal with Hydrodynamic Cavitation Process

In this study, the effect of cavitation was examined for the different time intervals from 0 to 150 mins. In hydrodynamic cavitation pump was used of 1 H.P capacity and reactor was 50 liters. With hydrodynamic cavitation, maximum COD removal achieved was 80.36% in 90 mins as shown in Fig.

V. CONCLUSION

The degradation of wastewater from pharmaceutical wastewater was investigated by the cavitation process. The cavitation process was done in two ways acoustic and hydrodynamic. Therefore, maximum efficiency of COD removal is achieved at 90 mins, 80.36% with hydrodynamic cavitation without any use of chemical.

Cavitation is eco-friendly way to reduce the pollution load of wastewater. These processes differ from the other treatments processes because wastewater compounds are degraded rather than concentrated or transferred into a different phase and secondary waste materials are not generated. Sludge generation is very less compared to other processes.

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Response of Traditional Aromatic Rice (*Oryza Sativa* L.) Cultivars to Zinc Fertilization Strategies under Eastern Himalayan Region

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Abstract— *The present study aimed to evaluate the effect of zinc fertilization strategies on growth, yield, and nutrient uptake in two traditional aromatic rice cultivars, Tulaipanji and Kalonunia, under acidic soil conditions of North Bengal. The field experiment was conducted during the kharif seasons of 2022 and 2023 at Uttar Banga Krishi Viswavidyalaya, Pundibari, using a Split Plot Design with three replications. The main plot comprised two varieties, while the sub-plot included six zinc management treatments, involving combinations of soil-applied, foliar-applied, and nano zinc sources.*

Results revealed significant varietal differences, with Kalonunia consistently outperforming Tulaipanji in terms of plant height, number of tillers, chlorophyll index, grain yield, and nutrient uptake. Among zinc treatments, the integrated application of 2.5 kg Zn ha^{-1} as basal + 100 ppm nano Zn foliar at panicle initiation + 0.5% Zn foliar spray at grain filling (Z_3) showed superior performance across both years. Z_3 recorded the highest grain yield (2.77 t ha^{-1}), grain number per panicle (121.69), and maximum uptake of nitrogen, phosphorus, potassium, and zinc in straw. This enhanced performance is attributed to improved zinc bioavailability and the synergistic action of multiple application timings and forms.

The findings emphasize the efficacy of integrated zinc management, particularly involving nano and foliar zinc application, in enhancing yield and nutritional quality of aromatic rice cultivars. Such strategies hold promises for sustainable crop production and combating micronutrient malnutrition in zinc-deficient regions.

Keywords— Aromatic rice, nano zinc, biofortification, zinc fertilization, nutrient uptake, yield enhancement, Kalonunia, Tulaipanji.

I. INTRODUCTION

Rice is a staple food for the Asia-Pacific region, contributing approximately 21% of global energy and 15% of protein requirements (Sengupta *et al.*, 2019). Among rice types, aromatic rice occupies a niche segment known for its aroma, fine grain, and superior cooking quality. West Bengal holds a rich diversity of traditional aromatic landraces, including Tulaipanji and Kalonunia, which are medium-grained types valued both domestically and for export potential (Mondal *et al.*, 2011).

Despite its importance, rice is nutritionally poor, particularly in micronutrients like zinc (Zn) and iron (Kumar *et al.*, 2020). Micronutrient malnutrition or "hidden hunger" is widespread among resource-poor populations, largely due to low Zn bioavailability in cereal-based diets (Bouis and Saltzman, 2017). Zinc plays a vital role in numerous physiological and biochemical processes including enzyme activity, gene expression, photosynthesis, and stress tolerance (Hefferon, 2019). Moreover, higher Zn in rice straw is crucial for livestock nutrition in developing countries.

Agronomic biofortification, especially using Zn fertilizers, has emerged as a strategy to improve Zn content in grains, thereby enhancing both human and animal nutrition (WHO, 2002). Ahmed *et al.*, 2021 also found tallest plant and maximum leaves of maize with soil application of 10 kg Zn ha $^{-1}$. Recent advances advocate the use of zinc nanoparticles (ZnNPs), which offer controlled nutrient release, improved uptake efficiency, environmental safety, and economic benefits (Iqbal *et al.*, 2020). Thus, ZnNPs hold promise for enhancing rice yield and nutritional quality, particularly in aromatic cultivars with export value. Based on above mentioned fact present study was undertaken at Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar during two consecutive *kharif* 2022 and 2023 to study the comparative response of zinc fertilization on traditional aromatic cultivars.

II. MATERIALS AND METHODS

Present research was conducted at the instructional farm of Uttar Banga Krishi Viswavidyalya, Pundibari, Cooch Behar, West Bengal during the *kharif* season of 2022 and 2023. The experiment was fitted out in Split Plot Design with three replications. The main plot included two variety: V_1- Tulaipanji and V_2 - Kalonunia and sub plot treatment consisting of Z_1 - 5 kg Zn (soil) as basal, Z_2 - 2.5 kg Zn (soil) as basal + 2.5 kg (soil) maximum tillering, Z_3 - 2.5 kg Zn (soil) as basal+100 ppm nano Zn at PI + 0.5% Zn FA at grain filling, Z_4 - 0.5% Zn FA at PI + 0.5% FA at grain filling, Z_5 -100 ppm nano Zn at PI + 100 ppm nano Zn at grain filling, Z_6 - Control. Soil of the experimental field was acidic in reaction having pH value 5.84 with medium in organic carbon (0.69%), low in available nitrogen (169.27 kg ha^{-1}), medium in available phosphorus (18.91 kg ha^{-1}), potassium (140.82 kg ha^{-1}) and available zinc (0.77 mg kg^{-1}). The both varieties used in the experiment sown in 23rd July and 28th July during 2022 & 2023 respectively, with a row to row and plant to spacing of 25 x 20 cm. Plot size of 5 m x 4 m was maintained along with seed rate @ 30 kg ha^{-1}. Vermicompost @ 3 t ha^{-1} was applied as basal in each plot. Weather conditions of the experimental period included a total rainfall of 2602.50 mm and 3169.30 mm for 2022 and 2023 respectively, and an average maximum and minimum temperature range of 33.56 °C to 8.49°C in 2022 and 32.86°C to 12.70 °C in 2023 during the June to December.

Soil application of zinc through Zinc Sulphate Heptahydrate (21% Zn), foliar application through Chelated Zinc (Zinc EDTA 12% Zn) and nano zinc refers to a product from Sisco Research Laboratories (SRL) that involves zinc nanoparticles, specifically zinc oxide nanoparticles (ZnO NPs, 50nm, 99.9%). Standard agronomic practices were followed to keep the field devoid of weeds, insects and fungi.

Key growth parameters including plant height, number of tillers m^{-2} and chlorophyll were recorded 30 days interval starting from 30 days after sowing to harvest. Among the yield attributes total no of grain panicle^{-1}, spikelet sterility was recorded at harvest from randomly selected plants. Grain from the corresponding net plot area were sun dried for 4 days and then threshing was done. The grain weight of individual plot was recorded and was converted to tonnes ha^{-1}. The experimental data were analysed using statistical software SPSS version-20. For determination of critical difference at 5% level of significance Fisher and Yates (1963) table was consulted.

TABLE 1
RESPONSE OF ZINC FERTILIZATION ON GROWTH ATTRIBUTES OF AROMATIC RICE CULTIVARS

Treatments	Plant Height (cm)				No of tiller m^{-2}				Chlorophyll Index			
	30 DAT	60 DAT	90 DAT	120 DAT	30 DAT	60 DAT	90 DAT	120 DAT	30 DAT	60 DAT	90 DAT	120 DAT
Variety												
V_1	64.14	108.70	119.54	127.28	223.91	330.81	280.29	257.40	213.04	168.98	101.49	67.83
V_2	68.33	122.73	133.05	138.04	298.37	383.06	320.14	294.05	220.28	183.43	105.12	70.33
SE m (±)	0.81	1.07	1.43	1.47	4.21	4.06	4.27	4.82	4.57	3.18	1.32	0.77
CD (P=0.05)	3.17	4.19	5.62	5.79	16.53	15.93	16.77	18.38	17.94	12.50	5.21	3.01
Zinc management												
Z_1	70.84	117.78	124.26	128.91	276.70	377.70	279.92	260.33	230.96	179.17	99.26	64.92
Z_2	68.06	120.25	125.72	130.97	264.94	386.61	290.49	268.82	219.41	184.89	102.86	69.04
Z_3	67.79	115.74	130.54	139.15	263.81	366.40	332.76	300.61	217.92	175.61	109.40	77.04
Z_4	64.03	114.28	128.65	136.62	255.97	342.91	319.28	290.13	212.20	173.32	107.93	72.75
Z_5	63.95	113.37	127.19	134.56	252.94	335.51	307.99	283.87	210.34	172.70	107.11	71.90
Z_6	62.75	112.87	121.42	125.73	252.50	332.49	270.84	250.61	209.12	171.55	93.27	58.84
SE m (±)	1.10	1.98	1.95	2.08	4.22	5.88	4.57	7.49	3.58	2.62	2.02	1.13
CD (P=0.05)	3.13	5.69	5.57	5.93	12.07	16.80	13.06	21.40	10.22	7.49	5.76	3.22

III. RESULTS AND DISCUSSION

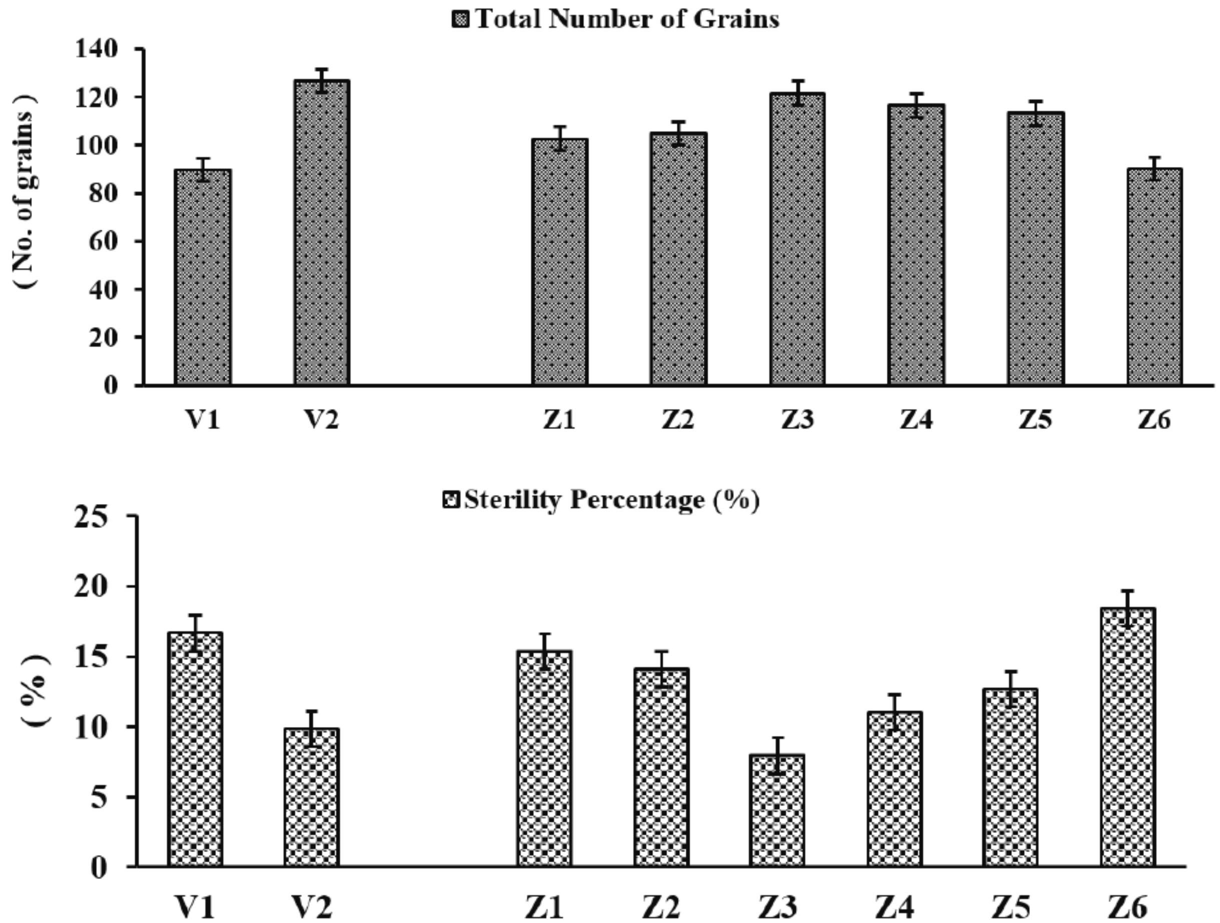
3.1 Growth parameters:

Plant height (cm), no of tiller m^{-2} is a critical agronomic trait directly associated with the overall biomass accumulation, photosynthetic potential, and sink capacity of cereal crops like rice. Based on the pooled results, a significant varietal influence on plant height, no of tiller and chlorophyll index was observed across all growth stages of aromatic rice. Kalonunia (V_2) consistently recorded greater plant height, no of tiller and chlorophyll index than Tulaipanji (V_1), demonstrating its superior vegetative vigour and growth potential (Table 1). This consistent superiority in plant stature observed in Kalonunia can be attributed to its intrinsically robust plant architecture, better nutrient responsiveness, and efficient translocation of assimilates.

Among the level of zinc at 30 days after transplanting (DAT), Z_1 (5 kg Zn ha^{-1} as basal) resulted the highest plant hight (70.84 cm), no of tiller m^{-2} (276.70) and chlorophyll index (230.96). At 60 DAT, the tallest plant hight (120.25 cm), highest no of tiller m^{-2} (386.61) and chlorophyll index (184.89) were recorded under Z_2. At 90 DAT and harvest stage, the highest plant height (130.54 cm and 139.15 cm, respectively), no of tiller m^{-2} (332.76 and 300.61) and chlorophyll index (108.40 and 77.04) was obtained in Z_3 followed by Z_4 (0.5% foliar Zn at PI + grain filling), while Z_6 registered the lowest values. These treatments help delay senescence, improve nutrient mobilization, and support assimilate partitioning, which collectively sustain productive tillers through to maturity, (Broadley *et al.*, 2007). These findings underscore the importance of foliar and nano zinc application during the panicle initiation and grain filling stages. Zinc is known to improve chlorophyll synthesis and delay senescence, thus prolonging the photosynthetic duration and promoting further growth (Fageria *et al.,* 2002).

3.2 Yield attributes and yield:

Yield components such as total no of grain $panicle^{-1}$, grain yield (t ha^{-1}), sterility % a significant variation was observed as influenced by varietal differences (Fig. 1). Among the two aromatic rice cultivars, Kalonunia (V_2) exhibited higher grain count $panicle^{-1}$ (126.78) and grain yield (2.48 t ha^{-1}), whereas Tulaipanji recorded highest sterility (16.66%). Better responsiveness of Kalonunia to zinc fertilization may be attributed to improved nutrient uptake and assimilate partitioning towards reproductive structures, thereby resulting in greater yield.



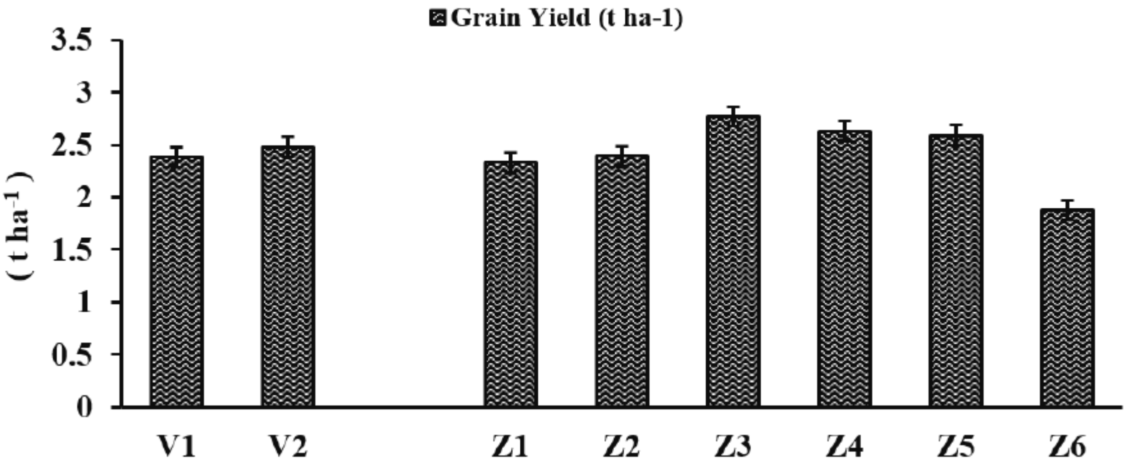


FIGURE 1: Response of Zinc Fertilization on Yield Attributes and Yield of Aromatic Rice Cultivars

Among the various zinc management treatments, the treatment Z_3 (2.5 kg Zn (soil) as basal + 100 ppm nano Zn at PI + 0.5% Zn FA at grain filling) resulted the highest no of grain panicle^{-1} (121.69) and grain yield (2.77 t ha^{-1}) this was followed by Z_4 (116.64 and 2.63 t ha $^{-1}$), Z_5 (113.26 and 2.59 t ha^{-1}). The markedly lower yield observed under the control treatment Z_6. Whereas the higher sterility percentage obtained from the Z_6 treatment (18.45 %) followed by Z_1 and Z_2. The superior performance of Z_3 can be attributed to the synergistic effect of basal, nano, and foliar zinc applications, which likely improved zinc availability during key phenological stages, enhanced enzymatic activities, and promoted efficient assimilate translocation and spikelet fertility, culminating in higher grain yield (Alloway, 2008; Cakmak, 2008).

3.3 Uptake of nitrogen, phosphorus, potassium and zinc in straw:

In case of nutrient uptake V_2 (Kalonunia) obtained highest nitrogen (31.08 & 38.32 kg ha^{-1}), phosphorus (6.45 & 8.64 kg ha^{-1}), potassium (53.60 & 64.28 kg ha^{-1}) and zinc (125.89 & 156.04 g ha^{-1}) uptake respectively during 2022 and 2023 over V_1 (Tulaipanji) (Table 2). This enhanced uptake capacity in Kalonunia may be attributed to its superior nutrient remobilization efficiency and enhanced translocation dynamics which enhance the nutrient uptake in straw.

TABLE 2
RESPONSE OF ZINC FERTILIZATION ON NUTRIENT UPTAKE BY AROMATIC RICE CULTIVARS

Treatments	Nitrogen uptake by straw (kg ha^{-1})		Phosphorus uptake by straw (kg ha^{-1})		Potassium uptake by straw (kg ha^{-1})		Zinc uptake by straw (g ha^{-1})	
	2022	2023	2022	2023	2022	2023	2022	2023
Variety								
V_1	26.74	32.71	6.02	8.22	49.48	60.61	104.19	136.48
V_2	31.08	38.32	6.45	8.64	53.60	64.28	125.89	156.04
SE m (±)	1.11	1.49	0.04	0.05	0.32	0.42	1.37	2.71
CD (P=0.05)	NS	NS	0.26	0.30	1.94	2.53	8.33	16.47
Zinc management								
Z_1	26.40	32.39	6.02	8.29	48.00	59.76	94.28	126.02
Z_2	27.68	34.22	6.04	8.35	49.58	60.72	106.60	140.59
Z_3	35.77	41.96	6.65	8.94	58.63	69.54	164.70	198.31
Z_4	32.14	39.27	6.42	8.63	55.16	65.85	134.31	164.12
Z_5	30.24	38.08	6.38	8.58	54.44	64.67	121.30	151.73
Z_6	21.21	27.17	5.90	7.81	43.41	54.15	69.06	96.79
SE m (±)	1.07	1.27	0.20	0.18	1.84	1.03	6.36	5.71
CD (P=0.05)	3.15	3.76	0.59	0.77	5.43	3.04	18.75	16.85

Application of 2.5 kg Zn (soil) as basal + 100 ppm nano Zn at PI + 0.5% Zn FA at grain filling (Z_3) recorded significantly highest nitrogen (35.77 & 41.96 kg ha^{-1}), phosphorus (6.65 & 8.94 kg ha^{-1}), potassium (58.63 & 69.54 kg ha^{-1}) and zinc (164.70 & 198.31 g ha^{-1}) uptake respectively during 2022 and 2023 followed by Z_4 (0.5% Zn FA at PI + 0.5% at grain filling) and Z_5 (100 ppm nano Zn at PI + 100 ppm nano Zn at grain filling). The use of nano zinc, in particular, is known to increase zinc bioavailability due to its higher surface area and reactivity, enabling more efficient nutrient uptake and utilization by plant tissues (Dimkpa & Bindraban, 2016).

IV. CONCLUSION

The present investigation demonstrated that varietal differences and zinc management practices significantly influenced the growth, yield, and nutrient uptake of aromatic rice under acidic soil conditions of North Bengal. Among the two tested cultivars, Kalonunia (V_2) consistently outperformed Tulaipanji (V_1) in terms of plant height, tiller number, chlorophyll index, grain yield, and nutrient uptake, highlighting its superior vegetative vigor and efficient resource use.

Zinc application strategies significantly enhanced growth parameters and yield components. The integrated treatment involving basal soil application of zinc along with foliar and nano zinc application at critical phenological stages (Z_3: 2.5 kg Zn ha^{-1} as basal + 100 ppm nano Zn at panicle initiation + 0.5% Zn foliar spray at grain filling) was found to be the most effective. This treatment consistently recorded the highest grain yield, grain count $panicle^{-1}$, and uptake of nitrogen, phosphorus, potassium, and zinc in both years of study. The effectiveness of Z_3 may be attributed to improved zinc bioavailability and synergistic effects of multiple application modes, enhancing enzymatic activity, spikelet fertility, and nutrient translocation during critical growth stages.

The findings underscore the potential of nano and foliar zinc fertilization, in conjunction with conventional soil application, to boost the productivity and nutritional quality of aromatic rice cultivars especially those like Kalonunia with strong genetic potential. These results support the use of integrated zinc management as a sustainable agronomic approach for improving rice yield and addressing zinc malnutrition in resource-poor regions.

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Sericulture in Andhra Pradesh: A Sustainable Approach to Sericulture Enterprise and Rural Youth Empowerment

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Abstract— *Silk has long been admired for its richness, beauty, and timeless elegance. Even today, no fabric can rival its natural shine and luxurious appeal. Celebrated as the "queen of textiles," silk has become deeply embedded in India's culture and traditions, often worn during religious rituals and festival occasions. Andhra Pradesh, a state with a rich cultural heritage, stands as the second-largest producer of mulberry silk in India and is widely recognized for its internationally acclaimed bivoltine silk. Sericulture is not only a vital contributor to the state's economy but also provides regular employment, especially to rural youth.*

Andhra Pradesh located on the southeastern coast of India, Andhra Pradesh comprises two main regions-Coastal Andhra and Rayalaseema. In today's context, the youth are seen as the foundation and driving force of the nation's future. With creativity, energy, and innovation, young people possess the potential to bring about transformative change. However, rural youth often face significant challenges in securing sustainable livelihoods. Their talents remain underutilized due to limited opportunities and systemic neglect.

To address this gap, it is crucial to make agriculture and allied sectors—such as sericulture and animal husbandry—more appealing and economically viable for the younger generation. As a labor-intensive, rural-based agro-industry, sericulture offers vast employment potential and helps prevent migration from villages to cities. Its strong integration of on-farm and off-farm activities has earned it recognition as a key driver for rural socio-economic development in India's largely agrarian economy. Therefore, engaging youth in agriculture and allied enterprises is essential to ensure the long-term sustainability of these sectors.

Keywords— Sericulture, Rural Youth, Enterprise, Opportunities, Empowerment.

I. INTRODUCTION

Youth are widely recognized as the driving force and foundational strength of any nation. India, with its predominantly young population, holds a unique demographic advantage. Young minds are known for their creativity, innovation, and ability to tackle seemingly impossible tasks. As the most dynamic and productive segment of society, youth play a central role in socio-economic progress. With the global population expected to reach 9 billion by 2050, youth will make up around 14% of that figure. This makes it imperative to engage their energy, maturity, and decision-making ability in meaningful development initiatives.

India's youth are highly diverse in terms of culture, religion, and socio-economic background. Such diversity demands targeted strategies to nurture their potential and address their specific needs. Youth also play a key role in conserving the nation's natural resources and ensuring sustainable development. Given that a large share of India's population still resides in rural areas, real national progress is closely tied to rural development. Currently, individuals aged 15 to 35 make up nearly one-third of the population, with approximately 80% of them living in rural regions. Research indicates that over 70% of India's poor also live in these rural areas, making poverty reduction a critical national priority. Thus, the future development of the country heavily depends on how effectively its youth are empowered and engaged.

1.1 Status of the Silk Industry:

Andhra Pradesh, located along India's southeastern coastline, comprises two key regions: Coastal Andhra and Rayalaseema. The state holds a prominent position in India's silk industry, being the second-largest producer of mulberry silk. It is especially renowned for producing high-quality, international-grade bivoltine silk. Sericulture is an integral part of the state's rural economy, offering significant employment opportunities and supporting traditional weaving centers such as Dharmavaram, Peddapuram, Mangalagiri, Rayadurg, and Proddatur.

The Department of Sericulture, headquartered in Guntur and led by the Commissioner of Sericulture, oversees the promotion and development of silk production in the state. The department's mission is to boost the production of high-quality bivoltine silk (Grade 2A and above), while also creating sustainable rural employment.

Sericulture, as a labor-intensive and agro-based industry, has proven to be effective in preventing rural-to-urban migration. Its combination of on-farm and off-farm activities offers vast employment opportunities and has caught the attention of policymakers. As such, it has been identified as a strategic sector for rural socio-economic development in India's agrarian economy. Involving youth in this sector is crucial to both ensuring their livelihoods and achieving long-term sustainability in agriculture and allied enterprises.

1.2 The Need for Youth Engagement:

India is home to a large number of educated yet untrained and under-skilled rural youth. While many of them are socially aware and eager to contribute to their communities, they lack access to the practical skills and opportunities necessary for sustainable livelihoods. Directed and structured engagement of youth energy is essential for healthy rural development.

Uncertainties of traditional agriculture—due to factors such as erratic monsoons and volatile markets—there is a pressing need for governments to initiate youth-centric programs that promote scientific and sustainable farming practices. Agriculture and its allied sectors must be made intellectually stimulating and financially rewarding to attract and retain the interest of young people.

To this end, establishing agri-business centers, agri-clinics, and farm schools is vital. These institutions can serve as platforms for hands-on training, farmer-to-farmer learning, and knowledge sharing. Furthermore, emphasis must be placed on value addition to primary agricultural products to enhance income and improve livelihood sustainability.

II. OPPORTUNITIES IN SERICULTURE – REGULAR INCOME WITH MINIMUM GESTATION PERIOD

Sericulture presents a promising opportunity for rural development by ensuring a steady source of income with a relatively short gestation period. With domestic demand for silk consistently rising-and projections indicating this trend will continue over the next two decades-India is rapidly emerging as the world's largest consumer of silk. This growing demand opens up vast prospects for both horizontal (area-wise) and vertical (value-wise) expansion within the sericulture sector to meet the increasing needs of domestic and international markets.

To harness this potential, policymakers and industry stakeholders must take the initiative to introduce sericulture into new and unexplored regions. In this context, engaging youth in agriculture and allied sectors, including sericulture, becomes crucial. Youth are typically more open to adopting and implementing new technologies, which can accelerate growth and innovation in agriculture-based enterprises.

The Government of India continues to provide comprehensive support to Andhra Pradesh to enhance sericulture development across all domains. The focus is on maximizing benefits from existing capacities while also building new infrastructure. Key initiatives include the establishment of common facility centers for farm mechanization, silkworm seed production, reeling, spinning, and weaving units. These interventions aim to position Andhra Pradesh as the future "Silk Hub of India," generating rural self-employment, preserving traditional practices, and aligning with the vision of "Make in India" in an eco-friendly manner.

A major step in this direction has been the Silk Samagra program—a central sector scheme launched by the Central Silk Board. Implemented both directly and through state governments, this scheme supports various beneficiary-oriented interventions across mulberry, vanya, and post-cocoon sectors. It includes research-backed packages developed by scientific institutions and focuses on enhancing productivity, quality, and employment in rural areas. The major areas of intervention include:

- Expansion of host plant cultivation

- Strengthening silkworm seed infrastructure
- Development of farm and post-cocoon facilities
- Modernization of reeling and processing technologies
- Capacity building through training and enterprise development

TABLE 1
RAW SILK PRODUCTION IN INDIA

Particulars	Unit	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24
Mulberry plantation	ha	235001	239967	237578	242277	253182	263352
Mulberry raw silk production							
bivoltine	MT	6987	7009	6783	7941	8904	9675
Cross breeds	MT	18357	18230	17113	17877	18750	20217
Total	MT	**25344**	**25239**	**23896**	**25818**	**27654**	**29892**
Vanya silk production							
Tasar	MT	2981	3136	2689	1466	1318	1586
Eri	MT	6910	7204	6946	7364	7349	7183
Muga	MT	233	241	239	255	261	252
Total	**MT**	10124	10581	9874	9085	8928	9021
Total raw silk production	**MT**	**35468**	**35820**	**33770**	**34903**	**36582**	**38913**

Source: Central silk board, Bangalore

Although Andhra Pradesh has suitable climatic conditions for cultivating multiple silk varieties—mulberry, tasar, and eri—only mulberry and tasar are currently practiced on a commercial scale. With strategic implementation of developmental schemes, the focus has now shifted to boosting bivoltine silk production, which offers superior quality and higher market value.

Sericulture has emerged as a key employment generator in Andhra Pradesh, contributing to poverty reduction and inclusive growth. As a labor-intensive, rural agro-industry, it plays a crucial role in preventing rural-to-urban migration by offering viable livelihood options locally. The industry's structure—spanning from cultivation to weaving—makes it particularly suited for women and unemployed rural youth. Activities such as mulberry cultivation, cocoon rearing, reeling, twisting, and weaving can be integrated with household responsibilities, making sericulture both accessible and empowering.

Moreover, sericulture stands out for its low initial investment, short crop cycles, and continuous income potential. It directly supports the raw material needs of the silk weaving industry, ensuring a complete value chain from farm to fabric. These advantages have made sericulture a sustainable enterprise in only a few countries globally—India being one of the notable success stories.

Recognizing the sector's alignment with national development goals, including the Millennium Development Goals (MDGs), both the Central and State Governments have initiated several programs to promote sericulture as a tool for inclusive growth, rural employment, and socio-economic development.

III. STATUS OF SERICULTURE AND ENTREPRENEURIAL CONSTRAINTS IN ANDHRA PRADESH

Andhra Pradesh holds a distinct position in India's silk industry, producing three of the four major varieties of silk—mulberry, tasar, and eri. The state also boasts a rich weaving heritage, supported by over one lakh handlooms. Andhra Pradesh ranks first in unit productivity and second in total silk production after Karnataka. As a rural, agro-based industry, sericulture has now spread across almost all districts, contributing significantly to the rural economy (Seshagiri et al., 2003).

Over the past decade, many cotton weavers from regions like Rayadurg and Proddatur have shifted to silk weaving due to higher income potential. Districts like Anantapur lead in mulberry cultivation and cocoon production, with Rayalaseema, particularly Anantapur and Chittoor, emerging as sericulture hubs. The sector not only offers direct employment to farmers but also generates indirect jobs in reeling, twisting, dyeing, weaving, block printing, and manufacturing of sericulture tools and equipment (Seshagiri and Ganapathi Rao, 2002). The silk production trend in Andhra Pradesh is presented in table 2.

Sericulture is both a cultural legacy and a livelihood in Andhra Pradesh. However, despite its potential, entrepreneurs face several challenges that hinder sustainability:

- Unstable prices and irregular availability of quality silkworm seed and other inputs
- Inadequate technical support and extension services
- Low rainfall and declining groundwater levels, affecting mulberry cultivation
- Harsh environmental conditions (e.g., high temperatures and humidity in coastal regions)
- Shortage of skilled labour to sustain cocoon production and post-cocoon operations
- Limited financial support and coordination among related departments

To address these constraints, the Government of Andhra Pradesh provides financial and infrastructural support to entrepreneurs under various schemes (as detailed in Table 3).

TABLE 2
SILK PRODUCTION TRENDS IN ANDHRA PRADESH

S. No	Variety	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24
1	Mulberry plantation (ha)	41915	44607	47363	50731	54971	58283
2	Mulberry raw silk (MT)						
	A) Bivoltine	1465	1446	1480	1624	1930	2308
	B) Cross breeds	6011	6511	6941	7207	7382	8181
3	**Total**	**7476**	**7957**	**8420**	**8832**	**9311**	**10489**
4	**Tasar**	5	4.5	1	2	1	2
5	**Grand total**	**7481**	**7961.5**	**8422**	**8834**	**9312**	**10492**

Source: department of sericulture, Andhra Pradesh.

TABLE 3
FINANCIAL ASSISTANCE PROVIDED BY THE GOVERNMENT FOR SERICULTURE FARMERS

S. No	Item/ Activity	Cost Rs.	Subsidy/Incentive Rs.
Mulberry propogation			
1	V1 saplings/acre	14,000	10,500
2	Tree mulberry plantation/acre	45,000	22,500
3	Soil enrichment (organic fertilizer like neem cake	10,000	5000
4	Micronutrients growth promoter	1500	750
5	Drip irrigation /one acre APMIP	1,50,000	1,35,000
Rearing shed, Veranda, Equipment's, Disinfectants, etc			
6	Model 1; rearing shed 50 x 20x 12-15 feet	2,75,000	82,500
7	Model 2; rearing shed 30x20x12-15 feet	1,75,000	87,500
8	Rearing shed for SC farmers	1,75,000	1,57,000
9	Rearing shed for ST farmers	2,00,000	1,80,000
10	Low cost shed including shoot stand	2,75,00	1,37,500
11	Construction of a veranda to a rearing shed	------	22,500
12	Rearing equipment's	70,000	35,000
13	Rearing equipment SC and ST farmers	70,000	63,000
14	Brush cutter farm mechanization	24,090	10,000
15	Secateurs	1,400	700
16	Disinfectants	5,000	3,750
17	Establishment of chawki rearing center and equipment's		4,20,000
18	Incentive on chawki silkworms/ BV/100Dfls	----	750
19	Plastic mountages	20,720	19,330
20	Plastic trays	6000	4,500
21	Production incentive for CB cocoons per Kg		10(20)
22	Production incentive for BV cocoons per Kg		50

Source: Department of sericulture Andhra Pradesh

IV. CHALLENGES FACED BY YOUTH IN SERICULTURE

Despite its potential to offer income and stability, youth involvement in sericulture and allied enterprises remains limited due to multiple structural and social challenges:

4.1 Limited Access to Skills and Information:

Youth in rural areas often lack access to quality education, agricultural training, and technology. Knowledge transfer traditionally occurs within families, but modern sericulture demands up-to-date information on markets, finance, water management, processing, and packaging—areas where youth are underserved.

4.2 Restricted Access to Land:

Increasing population pressure and land fragmentation have reduced the availability of agricultural land, making farming a non-viable option for many youth. Land not only provides food security but also supports rural employment and links urban markets through agri-produce.

4.3 Inadequate Financial Services:

Youth in agriculture often struggle to access affordable loans. While large industrialists secure loans easily, farmers face high interest rates, strict conditions, and crop risks. In cases of default or failure, they face severe consequences unlike their urban counterparts. Financial institutions must ensure affordable and inclusive lending to young entrepreneurs.

4.4 Barriers to Green Jobs:

There is untapped potential for green jobs that support sustainability and poverty reduction. However, youth lack technical skills, and even those with agricultural degrees often prefer salaried employment over farming. Investment in vocational training and enterprise development is crucial to change this mindset and empower youth toward self-employment.

4.5 Poor Market Access:

Limited access to input and output markets forces youth to rely on middlemen, reducing their earnings. Developing robust market linkages, cooperatives, and farmer-producer organizations (FPOs) is necessary to ensure fair pricing and transparency.

4.6 Minimal Role in Policy-making:

Youth are often excluded from decision-making processes. Policies are mostly designed top-down and may not reflect grassroots realities. Token participation, poor implementation, and bureaucratic hurdles reduce the effectiveness of youth-centric schemes. Empowering youth to participate in policy dialogues and feedback mechanisms can improve the relevance and impact of government programs.

V. EMPLOYMENT POTENTIAL OF SERICULTURE WITH LOW INVESTMENT

Sericulture offers significant employment potential even with minimal initial investment, making it an ideal enterprise for rural youth and women. Key features that make sericulture a powerful tool for inclusive development include:

- Short gestation period and multiple crop cycles per year
- Continuous income through integrated activities (mulberry farming, cocoon rearing, reeling, twisting, weaving)
- Low capital requirement and suitability for small landholdings
- High employment per unit area compared to other crops
- Compatibility with household-level work, especially beneficial for women
- Vital contribution to the raw material supply chain for the silk weaving industry
- Strong potential to reduce rural-to-urban migration

Globally, sericulture has struggled to sustain in many countries. However, India stands out as a success story, largely due to strong government support, traditional skillsets, and rural labor availability.

With alignment to sustainable development and poverty alleviation goals, the Government of India and State Governments continue to implement several schemes that promote youth involvement, infrastructure creation, and enterprise development in the sericulture sector. These efforts make sericulture a viable pathway for rural economic transformation and youth empowerment.

VI. EMPLOYMENT AND ECONOMIC POTENTIAL OF SERICULTURE

Sericulture is a highly labor-intensive industry, creating approximately 11 person-days of employment for every kilogram of raw silk produced through both on-farm and off-farm activities. This employment potential, particularly in rural areas, surpasses that of many other industries, making sericulture a valuable instrument for rural development. The practice effectively contributes to addressing unemployment and poverty, with the highest labor force participation rate compared to other rural livelihoods.

Mulberry sericulture involves two major phases: cultivation of mulberry for leaf production and rearing of silkworms for cocoon output. Mulberry plantations begin yielding within six months and can remain productive for 15–16 years with minimal maintenance. Compared to other crops, which typically require several months to harvest, mulberry leaves can be harvested every 22–28 days. With proper management and modern techniques, farmers can earn more than ₹1,00,000 per acre annually, making sericulture a highly profitable agricultural venture that promotes youth employment and economic empowerment.

VII. TECHNOLOGICAL ADVANCEMENTS AND EXPANSION

The introduction of new techniques in mulberry farming, silkworm breeding, and improved hybrid seeds has significantly transformed the silk industry. These innovations are designed to be cost-effective and suited for small-scale rural farmers. Simple to adopt and highly rewarding, these technologies are encouraging farmers across multiple districts to take up sericulture as a primary occupation. The spread of sericulture is helping rural communities achieve economic stability and move away from traditional subsistence farming.

Sericulture has evolved from a supplementary rural activity to a leading agricultural business that offers better returns than many conventional cash crops. Due to its inclusive and development-oriented nature, sericulture continues to gain importance in rural development policies. Additionally, it supports equitable income distribution, productive use of marginal land, and has high potential for exports.

TABLE 4
SERICULTURE ECONOMICS ONE ACER PLANTATION UNDER IRRIGATED CONDITIONS

S.No	Particulars	Rate (Rs)	Amount (Rs)
A. EXPENDITURE			
1	Cost of leaf production for 28MT of leaf per kg	R.s 2.28	65000
2	Cost of dfl's multi x bi 1250 dfls	R.s 500 per 100 dfl	6250
3	250 man days for rearing @20 man days for 100 dfls per 1250dfls	250/-	62,500.00
4	Non-recurring expenditure approx.		60,000.00
5	Recurring expenditure approx.		7000
	Total expenditure		**2,00,750.00**
B. RETURN			
6	Returns by selling 750kgs cocoons @60kgs cocoons /100 dfls (1250 dfls /year)	500/-per kg	3,75,000.00
NET RETURN in Rs; (B-A)			**1,74,250.00**
ASSUMPTIONS			
Mulberry variety		V1	
Silkworm hybrid		Multi x Bi	
Avg leaf yield/ acre @70 MT /ha/yr		28 MT/acre	
No.of dfls brushed /acre/year		1250 dfls	
Avg cocoon yield / 100 dfls		60kg	
Avg rate of cocoon /kg		500	

VIII. EMPOWERING YOUTH THROUGH SERICULTURE

In developing countries, around 85% of the youth population depend on agriculture for income. However, many young people are leaving agriculture due to lack of income, poor social recognition, and limited growth opportunities. Challenges such as climate change, shrinking land availability, and low profitability further discourage rural youth. While policies in the past, like those supporting the Green Revolution, empowered youth through infrastructure and training, today's agriculture needs a similar transformation.

8.1 Strategies to Attract Rural Youth to Sericulture:

8.1.1 Market Analysis and Youth Identification:

Policymakers should begin with analyzing current market trends and identifying youth interested in agriculture. These individuals can be trained and supported in sericulture to ensure long-term engagement.

8.1.2 Capacity Building and Skill Development:

Sericulture is a skill-based sector. Youth training platforms and practical capacity-building programs are essential. Innovations such as shoot rearing, plastic mountages, drip irrigation, foggers, and sprinkler systems should be demonstrated and promoted. Institutions like APSSRDI, with IGNOU, are already offering certificate courses in sericulture, developing skilled manpower in this domain.

8.1.3 Professionalizing Sericulture:

Introducing professional practices among rural youth through mobile camps and training from universities will improve profitability and sustainability in sericulture. Youth feedback must be regularly collected to improve systems and ensure relevance.

8.1.4 Access to Finance and Markets:

Youth often face difficulty in securing loans due to lack of collateral. Easy access to low-interest loans and streamlined procedures are essential to support youth-led sericulture businesses. Additionally, timely information on market prices and weather will help farmers optimize production and returns.

8.1.5 Crop Insurance:

Silkworm rearing is sensitive and susceptible to diseases. Bringing sericulture under crop insurance will protect farmers from losses and encourage greater adoption.

8.1.6 R&D and Innovation Networks:

Research and innovation are key to modernizing sericulture. A platform like "Young Professionals for Sericulture Research (YPPSR)" should be developed to enable youth-led research, knowledge exchange, and policy input. Integration of ICT tools and modern agri-education systems will benefit young entrepreneurs.

8.1.7 Seri Poly Clinics:

One-stop service centers (Seri Poly Clinics) must be established to provide necessary inputs and services to farmers directly at their doorstep, ensuring ease and accessibility.

8.1.8 Chawkie Rearing Centres (CRCs):

Establishing CRCs by youth with small landholdings can boost bivoltine silk production. These centers are crucial for early-stage silkworm development and can enhance crop success.

8.1.9 Supporting Youth-led Enterprises:

Qualified youth should be hired as extension agents and supported in launching their ventures in rearing, reeling, weaving, garment making, and marketing. Value-added products and Silk Mark outlets can enhance their market presence. Recognizing successful youth in sericulture through awards and showcasing their stories can inspire others.

8.2 Youth as Catalysts for Sericulture Growth:

Young people bring enthusiasm, creativity, and a willingness to adopt new technologies. Their involvement is key to modernizing and expanding the Indian silk industry. Rural youth already contribute significantly to core sericulture activities like land preparation, mulberry maintenance, and silkworm feeding.

India currently contributes over 18% to global silk production and stands as the second-largest producer of mulberry silk. Despite this, productivity remains a challenge due to high production costs and limited use of technology. Engaging youth in sericulture can improve efficiency, reduce costs, and increase competitiveness in the global market.

In conclusion, empowering rural youth through targeted programs, education, financial access, and professional support can revitalize Indian sericulture. With proper guidance and opportunity, youth can transform sericulture into a thriving, modern, and inclusive industry.

IX. CONCLUSION

Most rural youth perceive limited prospects in agriculture and sericulture due to challenges such as unpredictable weather, lack of infrastructure, unstable income, and low profitability. However, despite these obstacles, today's youth remain hopeful, energetic, and determined to reshape the rural economy. They are increasingly interested in becoming agri-preneurs and seri-preneurs, actively engaging in all aspects of the value chain — from production and processing to marketing.

With growing awareness of climate change and environmental concerns, rural youth are emerging as responsible stewards of sustainable farming practices. Many continue to support their families through seasonal farming and maintain strong connections between rural and urban areas by temporarily migrating during the agricultural off-season. Their willingness to adopt modern technologies and ICT tools reflects a shift toward more informed, efficient, and market-oriented farming.

It is evident that youth are one of the most valuable assets of the nation. Unfortunately, their full potential often remains underutilized due to limited access to resources, training, credit, and land. As the current generation of farmers ages, engaging the youth in agriculture and allied sectors like sericulture is critical for ensuring future food security, economic resilience, and sustainable rural development.

By empowering rural youth, recognizing their role in innovation, and addressing their challenges through policy and institutional support, we can foster inclusive growth and transform traditional agriculture into a dynamic and rewarding enterprise.

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Unlocking Biomass Potential: Renewable Energy Prospects in Assam

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Abstract— *Assam, with its rich biodiversity and vast agricultural landscape, holds immense potential for biomass-based renewable energy. Agricultural residues, forest biomass and dedicated energy crops present a sustainable and locally abundant energy source. Unlocking this biomass potential can contribute to addressing Assam's growing energy demands, especially in rural and peri-urban areas, while reducing dependency on conventional fossil fuels and alleviating waste management issues. Explores the opportunities for biomass energy in Assam and outlines strategies for its effective utilization. Key challenges, such as technological gaps, economic viability and infrastructural constraints, must be addressed to realize the full potential of biomass energy. Advanced technologies like carbon capture, utilization and storage (CCUS) can improve the efficiency and environmental sustainability of biomass projects. Additionally, strong policy frameworks, including financial incentives and research funding, are crucial to promote investment in biomass energy. Engaging local communities in the energy transition is essential for the successful adoption of biomass solutions. By fostering collaboration between the government, private sector and local stakeholders, Assam can unlock the full potential of its biomass resources, paving the way for a greener, more sustainable energy future. This paper highlights the need for coordinated efforts to harness biomass for renewable energy conversion in Assam.*

Keywords— Biomass Energy, Renewable Energy, Sustainability, Assam.

I. INTRODUCTION

Biomass and renewable energy are increasingly seen as vital components of a sustainable energy future in India, Assam is no exception. India has set ambitious targets for expanding its renewable energy capacity, aiming to reduce greenhouse gas emissions and enhance energy security. Biomass plays a crucial role in this transition due to its potential for cogeneration, lower emissions and the ability to provide decentralized energy solutions. The estimated biomass power generation potential in India is around 23,000 megawatts (MW), with sugar industry contributing about 5,000 MW from bagasse alone (Sahu *et al.*, 2015). This highlights the significant role biomass can play in India's energy mix as the country moves toward meeting its renewable energy goals.

In Assam, local biomass resources, such as bamboo dust from paper mills, provide an important opportunity for renewable energy generation. For example, the Cachar Paper Mill produces large quantities of bamboo dust waste, which can be converted into producer gas through gasification technology to generate electricity (Sinha *et al.*, 2011). This approach not only addresses waste management but also adds to the region's renewable energy portfolio. Such projects are economically viable and can create local jobs, stimulate the regional economy and promote sustainable energy practices (Kulkarni *et al.*, 2022). National and state-level policies are crucial for integrating renewable energy into broader development strategies. In Assam, biomass energy has the potential to support rural electrification and energy security, especially as energy access remains a challenge in many areas. Policies like Renewable Purchase Obligations (RPO) and feed-in tariffs incentivize investment in renewable technologies, fostering growth in the sector (Verma & Kumar, 2013). These initiatives aim to increase the share of renewable energy in India's overall energy mix, supporting the country's commitment to sustainability.

The renewable energy sector in India faces multiple challenges, including regulatory and financial barriers, as well as technological limitations (Sen *et al.*, 2016). Overcoming these obstacles is critical to unlocking the full potential of renewable energy, particularly in regions like Assam. Continued efforts to enhance energy efficiency and reduce fossil fuel reliance will be crucial to achieving India's climate targets and securing a sustainable energy future. In Assam, biomass offers a unique opportunity to address both energy and environmental concerns while promoting rural development. With a substantial portion of the population residing in rural areas, biomass resources—such as agricultural residues, wood and animal waste—can be harnessed to generate energy for cooking, electricity and industrial applications (Komanapalli, 2024). Moreover, biomass gasification technology can convert agricultural residues into synthetic natural gas, providing a renewable energy source that also helps manage waste. These initiatives also contribute to rural livelihoods, as projects such as bamboo dust-based gasification plants create local employment and income opportunities.

Transitioning to cleaner biomass technologies, particularly for cooking fuels, can also reduce health risks associated with indoor air pollution, which is a significant issue in rural households. Programs like the Pradhan Mantri Ujjwala Yojana demonstrate the government's commitment to promoting clean energy while addressing public health concerns (Das and Sen 2021). By fully harnessing its biomass resources, Assam can advance toward a more sustainable and equitable energy future.

II. BIOMASS RESOURCES IN ASSAM

Agricultural biomass in Assam plays a vital role in the state's economy and environmental sustainability, particularly due to its rice-dominant agricultural landscape. Rice cultivation, practiced three times a year, contributes significantly to Assam's agricultural GDP but also emits large amounts of methane (CH_4) and nitrous oxide (N_2O), highlighting the need for more sustainable practices (Mishra *et al.*, 2012). A promising approach is the conversion of agricultural biomass into biochar, which improves soil moisture retention and health. Assam produces significant agricultural waste, particularly post-harvest residues, which can be transformed into biochar, enhancing soil fertility and carbon sequestration (Deka *et al.*, 2019). Additionally, incorporating organic inputs like compost and biofertilizers can improve nutrient availability and soil microbial activity, offering a sustainable alternative to chemical fertilizers, which often degrade soil over time (Das *et al.*, 2022; Tomar & Saikia, 2022). Integrating technologies such as machine learning and precision agriculture could optimize resource use and improve crop management, contributing to a more resilient agricultural system (Borthakur, 2023). Additionally, integrated nutrient management practices have been shown to enhance soil properties and support sustainable production (Tomar & Saikia, 2022). Assam's agricultural biomass presents an opportunity to enhance both sustainability and productivity. By leveraging biochar, organic farming, and advanced technologies, the state can reduce environmental impact while improving the livelihoods of its farmers.

The forests of Assam are critical for biomass production, providing wood, leaves and other plant materials that contribute to local economies and ecological balance. These forests play a significant role in carbon sequestration, which is essential for mitigating climate change. However, sustainable management is crucial to maintaining their productivity. Intensive forest management practices, if not carefully monitored, can lead to soil degradation and reduced fertility, impacting long-term biomass yields (Blanco *et al.,* 2015). Moreover, deforestation driven by agricultural expansion and urbanization poses a significant threat to both biomass availability and biodiversity in the region. The loss of forest cover not only reduces the potential for biomass production but also disrupts the ecological services forests provide, such as habitat for wildlife and carbon storage (Halder *et al.,* 2023).

Biomass burning, a common practice in Assam, exacerbates environmental degradation. It contributes to air pollution and climate change, further affecting forest health and reducing biomass productivity (Borgohain *et al.,* 2023). Studies have shown that the particulate matter and greenhouse gases released from biomass burning in the region pose health risks and contribute to global warming (Gogoi *et al.,* 2017). Therefore, adopting sustainable forest management practices, such as afforestation, selective logging and community-based forest governance, can help mitigate these challenges while maintaining the productivity of Assam's forests.

Assam's rivers and wetlands also support diverse aquatic biomass, including fish and aquatic plants, which are vital to the local economy and diet. The region's aquatic ecosystems are under threat from climate change and flooding, which can disrupt these delicate environments (Halder *et al.,* 2023). Sustainable management of aquatic biomass can help provide alternative energy sources, enhance food security and protect these ecosystems. For instance, aquatic plants have been explored for their potential in bioremediation, helping to clean up polluted water bodies while providing nutrients for agricultural use (Bout *et al.*, 2019). This integration of aquatic biomass into sustainable agricultural practices can boost both environmental and economic resilience.

Assam's livestock sector also offers significant potential for biomass-based energy production. Animal waste, if managed properly, can be converted into biogas, a renewable energy source. Biogas production from animal waste not only provides clean energy but also reduces greenhouse gas emissions and improves soil fertility when the byproducts are used as fertilizers (Hazarika & Deka, 2013). However, challenges like inadequate animal health management and reactive vaccination programs limit the full potential of animal waste as a biomass resource (Hopker *et al.,* 2020). Addressing these challenges through improved animal health management and proactive vaccination efforts can enhance the sustainability of livestock biomass utilization, offering benefits for both energy production and rural livelihoods.

III. BIOMASS CONVERSION TECHNOLOGIES

Biomass conversion technologies are essential for transforming organic materials into valuable energy and chemical products. These technologies can be broadly categorized into thermochemical and biochemical conversion methods, each with distinct processes and applications. In the context of Assam, India, where biomass resources are abundant due to agricultural activities, understanding these conversion technologies is crucial for sustainable energy development.

3.1 Thermochemical Conversion:

Thermochemical conversion encompasses processes such as pyrolysis, gasification and combustion, which utilize heat to convert biomass into energy-dense intermediates. Pyrolysis, for instance, thermally decomposes biomass in the absence of oxygen, producing bio-oil, syngas and biochar (Dagle *et al.,* 2016; Kong *et al.,* 2013). Gasification converts biomass into syngas (a mixture of hydrogen and carbon monoxide) through partial oxidation, which can subsequently be used to produce electricity or transportation fuels (Gao *et al.,* 2021; Liu *et al.,* 2017). These processes are advantageous due to their high conversion efficiencies and the ability to process a wide variety of feedstocks, including lignocellulosic materials (Din, 2024; Rathore & Singh, 2021). Recent advancements in thermochemical technologies have improved the efficiency of biomass conversion. For example, the integration of catalytic processes in biomass-derived syngas conversion has shown promise in enhancing the yield of transportation fuels (Dagle *et al.,* 2016; Din, 2024). Additionally, the development of innovative pyrolysis methods, such as microwave-assisted pyrolysis, has demonstrated increased efficiency and reduced reaction times (Puligundla *et al.,* 2016). These advancements are particularly relevant for regions like Assam, where agricultural residues can be effectively utilized as feedstock for energy production.

3.2 Biochemical Conversion Technologies:

Biochemical conversion methods, including fermentation and anaerobic digestion, rely on biological processes to convert biomass into biofuels and chemicals. These methods are particularly effective for converting carbohydrate-rich biomass into bioethanol and biogas (Garba, 2021; Hakeem *et al.,* 2023). The efficiency of biochemical conversion is influenced by the composition of the biomass, particularly its cellulose, hemicellulose and lignin content, which can vary significantly among different feedstocks (Irmak, 2017). In Assam, the availability of diverse biomass sources, such as rice straw and sugarcane bagasse, presents opportunities for biochemical conversion technologies. For instance, the fermentation of lignocellulosic biomass can yield bioethanol, which is a sustainable alternative to fossil fuels (Nguyen, 2024). However, challenges such as low conversion rates and the need for effective pretreatment methods to break down complex biomass structures must be addressed to enhance the viability of biochemical processes (Hakeem *et al.,* 2023).

3.3 Emerging Technologies and Their Applicability in Assam:

Emerging technologies in biomass conversion, such as hydrothermal liquefaction and integrated biorefineries, are gaining attention for their potential to enhance biomass utilization (Ming, 2024; Skillen *et al.,* 2022). Hydrothermal liquefaction, which converts wet biomass into bio-crude oil under high temperature and pressure, offers a promising pathway for utilizing biomass that is otherwise difficult to process (Ming, 2024). Integrated biorefineries, which combine multiple conversion technologies, can optimize the production of fuels and value-added chemicals, making them particularly suitable for regions with abundant biomass resources like Assam (Ng *et al.,* 2015; Lap *et al.,* 2019). The applicability of these technologies in Assam is further supported by the region's rich biodiversity and agricultural practices. By leveraging local biomass resources, Assam can develop a sustainable bioeconomy that reduces reliance on fossil fuels while promoting environmental conservation (Kataya, 2023; Teh *et al.,* 2021). The integration of thermochemical and biochemical conversion technologies can also contribute to waste management strategies, transforming agricultural residues into valuable energy products and reducing environmental pollution (Kataya, 2023; (Rathore & Singh, 2021;). Diverse biomass conversion technologies available today, including thermochemical and biochemical methods, present significant opportunities for sustainable energy production in Assam, India.

By harnessing local biomass resources and adopting emerging technologies, Assam can pave the way for a greener energy future.

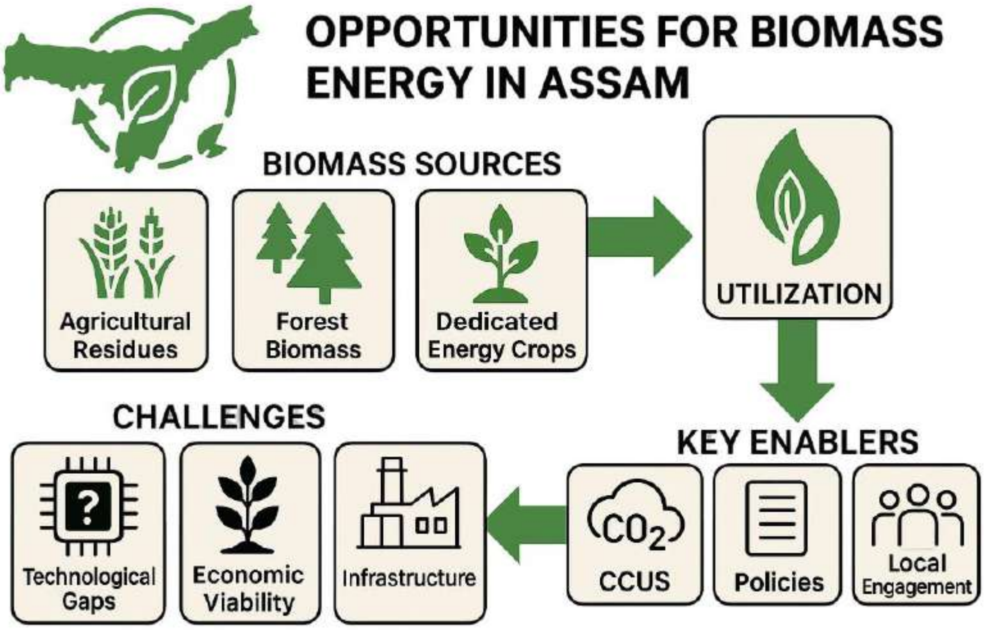

FIGURE 1: Opportunities for Biomass Energy in Assam

IV. CURRENT BIOMASS ENERGY PROJECTS IN ASSAM

Assam, various biomass energy projects are currently being developed, reflecting a growing recognition of the potential for biomass as a sustainable energy source. These projects primarily focus on utilizing agricultural residues, forestry waste and other organic materials to generate energy, which helps in reducing waste and contributes to energy security and environmental sustainability. One significant aspect of biomass energy in Assam is its potential for carbon stock enhancement. Research has shown that the biomass and carbon stock of tree species in tropical moist deciduous forests, such as those in the Kamrup Metropolitan District, can be substantial. A study estimated the biomass and carbon stock potential of 39 tree species, indicating the significant role of forestry in biomass energy production and carbon sequestration (Kalita, 2024). This aligns with the broader understanding that forests can serve as critical resources for biomass energy, contributing to both energy generation and ecological balance (Joshi, 2020).

The integration of biomass energy into the local energy mix is supported by various governmental and non-governmental initiatives aimed at promoting renewable energy sources. Community engagement in renewable energy projects has been highlighted as a crucial factor for success, as it fosters local buy-in and ensures that projects meet the needs of the community ("Engaging Communities In Renewable Energy Projects for Sustainable Development", 2024). This community-centric approach is vital in Assam, where local participation can enhance the sustainability and effectiveness of biomass energy initiatives. Economic viability of biomass energy projects in Assam is bolstered by the comparative cost-effectiveness of biofuels over fossil fuels. Studies have indicated that biofuels can be cheaper and more environmentally friendly, which is particularly relevant in the context of Assam's agricultural landscape, where biomass feedstock is readily available (Khan *et al.,* 2019). However, the successful implementation of these projects often requires supportive policies, including subsidies and regulatory frameworks that encourage investment in renewable energy (Khan *et al.*, 2019).

Furthermore, the potential for hybrid renewable energy systems (HRES) in Assam has been explored, particularly in the Cachar district. This research emphasizes the need for a comprehensive approach that combines various renewable sources, including biomass, to optimize energy production and ensure sustainability (Komanapalli, 2024). The integration of biomass with other renewable technologies can enhance energy reliability and reduce dependence on fossil fuels, thereby contributing to the region's energy transition goals. Current biomass energy projects in Assam are characterized by a strong emphasis on community involvement, economic feasibility and ecological sustainability. The region's rich biodiversity and agricultural resources provide a solid foundation for biomass energy development, which is further supported by research and policy initiatives aimed at promoting renewable energy sources.

V. SOCIO-ECONOMIC AND ENVIRONMENTAL BENEFITS

The socio-economic and environmental landscape of Assam is significantly influenced by various factors, including employment generation, rural development, energy security and environmental impacts. The interplay of these elements is crucial for understanding the overall development trajectory of the region.

5.1 Employment and Rural Development:

Employment generation in Assam is largely driven by agriculture and allied sectors, which contribute substantially to the state's Gross State Domestic Product (GSDP) (Choudhury & Easwaran, 2019). The implementation of government initiatives such as the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) has been pivotal in enhancing rural livelihoods, particularly for women (Bhattacharyya, 2016; Fraser, 2015). MGNREGA not only provides guaranteed employment but also empowers women by fostering financial independence, thereby enhancing their social status within families and communities (Phukan, 2021). Furthermore, the diversification of income sources through agricultural entrepreneurship, including horticulture and dairy farming, has been identified as a successful strategy for managing agrarian crises and improving rural incomes (Medhi, 2023; Haque & Barua, 2021). The micro, small and medium enterprises (MSMEs) sector also plays a crucial role in employment generation, especially in the context of rising unemployment rates in Assam (Sarmah *et al.,* 2021). The promotion of MSMEs has been linked to increased GDP and export potential, thus contributing to the economic resilience of rural areas (Sarmah *et al.,* 2021; Sukanya, 2018). Additionally, the rural non-farm employment sector has shown trends of both growth and decline, indicating the need for targeted policies to sustain employment opportunities (Saikia, 2018; Goswami & Bhattacharya, 2014).

5.2 Energy Security:

Energy security in Assam is increasingly being addressed through renewable energy initiatives, particularly solar power. The introduction of solar home lighting systems has been evaluated for its impact on rural livelihoods, demonstrating positive outcomes in terms of improved quality of life and economic stability (Barman *et al.,* 2017). This shift towards renewable energy not only enhances energy access but also contributes to environmental sustainability by reducing reliance on fossil fuels.

5.3 Environmental Impact:

The environmental implications of agricultural practices in Assam, particularly in sericulture, are significant. Assam is a leading producer of eri and muga silk, which are sensitive to climate variations (Das *et al.,* 2023; De & Das, 2010). The cultivation practices must adapt to changing climatic conditions to sustain production levels and, consequently, rural employment. Moreover, the impact of animal diseases, such as haemorrhagic septicaemia, poses a threat to dairy farming, which is vital for rural livelihoods (Shome *et al.,* 2019). Vaccination and biosecurity measures are essential to mitigate these risks and ensure the sustainability of livestock farming.

VI. CHALLENGES AND BARRIERS TO BIOMASS UTILIZATION IN ASSAM

The utilization of biomass energy in Assam faces a multitude of challenges and barriers that can be categorized into policy and regulatory challenges, technological and infrastructure barriers, financial and market barriers and social and cultural challenges. Each of these categories presents unique obstacles that hinder the effective adoption and implementation of biomass energy solutions in the region.

6.1 Policy and Regulatory Challenges:

In Assam, the biomass energy sector is significantly influenced by the existing policy framework, which often lacks coherence and comprehensive support for biomass initiatives. The absence of a unified biomass energy strategy, as observed in other regions like India, leads to inefficiencies in biomass utilization (Singh & Setiawan, 2013). Furthermore, local government policies may not adequately incentivize biomass energy projects, resulting in insufficient participation from farmers and energy producers ("Decision-Making Game and Policy Simulation of Biomass Energy Resources Based on Consideration of Behavioral Heterogeneity", 2020). The regulatory environment can also be complicated by overlapping jurisdictions and a lack of clarity regarding biomass resource management, which can deter investment and innovation in the sector.

6.2 Technological and Infrastructure Barriers:

Technological limitations pose a significant barrier to biomass utilization in Assam. The region lacks advanced technologies for biomass conversion processes such as gasification, pyrolysis and anaerobic digestion, which are essential for maximizing energy output from biomass (Makul *et al.,* 2021). Additionally, inadequate infrastructure for biomass collection, storage and transportation further complicates the supply chain, making it difficult for producers to deliver biomass efficiently to energy conversion facilities (Tun *et al.,* 2019). The need for technology optimization is critical, as many existing methods are not suited to the local context, leading to inefficiencies and increased emissions (Cheng, 2023).

6.3 Financial and Market Barriers:

Financial constraints are a major hurdle for the biomass sector in Assam. The high initial capital investment required for biomass energy projects, coupled with the uncertainty of returns, discourages potential investors. Moreover, market barriers such as fluctuating biomass prices and competition from cheaper fossil fuels create an unstable economic environment for biomass energy producers. The lack of financial incentives, such as subsidies or grants for biomass projects, further exacerbates these issues, making it challenging for stakeholders to commit to biomass energy initiatives (Shahzad *et al.,* 2023).

6.4 Social and Cultural Challenges:

Social acceptance and cultural perceptions of biomass energy also play a crucial role in its utilization. In Assam, traditional energy practices and a lack of awareness about the benefits of biomass energy can lead to resistance among local communities (Hazarika & Deka, 2013). Cultural barriers, including skepticism towards new technologies and energy sources, can hinder the adoption of biomass solutions (Pavan *et al.,* 2021). Additionally, the involvement of local communities in biomass energy projects is often limited, which can result in a disconnect between project developers and the communities they aim to serve (Tun *et al.,* 2019). Building trust and fostering community engagement are essential for overcoming these social barriers and ensuring the successful implementation of biomass energy projects.

VII. Policy Recommendations and Future Directions

The development of biomass energy in Assam offers a promising avenue for addressing the region's energy demands, enhancing sustainability and reducing reliance on non-renewable sources. With its rich biodiversity and extensive agricultural activities, Assam has significant potential for harnessing biomass, particularly from agricultural residues and dedicated energy crops. Studies by Hazarika and Deka (2013) emphasize the need for tailored biomass solutions to meet the varied energy needs of urban, peri-urban and rural areas. By converting agricultural waste into biomass energy, Assam can not only promote sustainable energy generation but also alleviate the pressure on conventional energy sources. For biomass energy projects to succeed, economic viability is crucial. Sinha *et al.* (2011) illustrates this through a case study on using bamboo dust for energy generation, offering a replicable model for other sectors. Incorporating carbon capture, utilization and storage (CCUS) technologies, as suggested by Krishnamoorti (2019), could further improve biomass project feasibility by reducing emissions and enhancing energy efficiency. A supportive policy framework is essential for promoting biomass energy in Assam. Policymakers should consider tax incentives, subsidies and research incentives to encourage investment and innovation in biomass technologies. Integrating biomass energy into Assam's broader energy strategies would strengthen its energy transition efforts. Local community engagement is vital for the long-term success of biomass initiatives. Educational programs and capacity-building efforts can ensure that communities are active participants in the adoption and use of biomass technologies. Vaish *et al.* (2022) emphasizes converting agricultural residues into biomass fuels, which not only promotes renewable energy but also addresses waste management issues.

VIII. Conclusion

Assam's abundant biomass resources, fuelled by its rich biodiversity and agricultural activities, present a major opportunity for renewable energy conversion. The region's agricultural residues, dedicated energy crops and forest biomass offer a sustainable energy source that can cater to the varying energy demands of rural, peri-urban and urban areas. By tapping into this potential, Assam can improve energy security while reducing its reliance on non-renewable resources. Additionally, converting agricultural and forest residues into biomass energy can provide a practical solution to waste management challenges. However, realizing the full potential of biomass energy in Assam requires overcoming significant hurdles. Economic challenges, infrastructure limitations and technological gaps remain obstacles. To ensure sustainable development, region-specific sustainability metrics are needed to evaluate the environmental, social and economic impacts of biomass projects. Integrating advanced technologies like carbon capture, utilization and storage (CCUS) can enhance the efficiency and environmental sustainability of biomass energy systems. In addition, strong policy support, including financial incentives and research funding, will be critical in fostering innovation and investment in the sector. Stakeholders must take collective action to harness Assam's biomass resources. Government bodies need to create enabling policies and infrastructure, while the private sector can drive technological advancements and investments in biomass energy. Local communities also play a key role and their active involvement is essential for the successful and sustainable adoption of biomass technologies. Educational initiatives and skill-building programs can empower these communities to become key participants in Assam's shift towards renewable energy. By making use of its extensive biomass resources, Assam has the chance to lead in renewable energy efforts. A unified approach involving the government, businesses and communities is crucial to achieving a more sustainable and environmentally friendly future for the region.

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Artificial Intelligence and Agricultural Risk Management for Smallholder Cowpea Farmers and Processors in Niger State, Nigeria

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Abstract— *This study investigates the role of artificial intelligence (AI) in agricultural risk management among smallholder cowpea farmers and processors in Niger State, Nigeria. Using a mixed-methods approach and a sample of 200 respondents, the study assessed socio-economic characteristics, AI awareness and adoption patterns, perceptions of AI tool functionality, influencing factors, and adoption challenges. Results revealed that 62% of respondents were male, 43% aged between 31–45 years, and 47% had only primary or no formal education. The average farm size was 1.86 hectares, and 69% were cooperative members. Awareness of AI technologies was moderate to high, with 68% aware of AI-based weather forecasting, 62% aware of pest detection tools, and 54% familiar with price prediction platforms. However, only 42% had adopted any AI tool, and just 29% found them easy to use. Perception scores were highest for AI in weather forecasting (mean=2.91), pest detection (2.76), and risk mitigation (2.81), while ease of use (2.38) and device compatibility (2.44) were below the acceptance threshold. Regression analysis identified educational level, digital literacy, AI awareness, and extension contact as significant at the 1% level. Gender, farm size, and cooperative membership were significant at the 5% level, while age and access to credit were weakly significant (10%). Marital status, farming experience, and perceived risk level were not significant. Kendall's Coefficient of Concordance (W=0.726, p < 0.001) revealed strong agreement on adoption challenges, with top-ranked constraints including low digital literacy (mean rank = 5.84), poor internet access (5.62), and high cost of digital tools (5.38).*

Keywords— ***Artificial Intelligence, Cowpea Farming, Agricultural Risk Management, Technology Adoption*.**

I. INTRODUCTION

Agriculture remains a critical pillar of Nigeria's economy, employing over 70% of the rural workforce and contributing significantly to national GDP, food security, and livelihoods (FAO, 2023; NBS, 2022). Among key staple crops, cowpea (*Vigna unguiculata*)—commonly known as black-eyed pea—plays a dual role: as a high-protein dietary staple and as a commercially valuable commodity for both rural farmers and urban markets (Kamilaris and Prenafeta-Boldú, 2018). Nigeria is the world's largest producer and consumer of cowpea, with an estimated annual production exceeding 3 million metric tonnes (Olawuyi and Ogunniyi, 2023; Adeyemi *et al.,* 2025). Despite its economic and nutritional importance, cowpea production in Nigeria remains highly susceptible to a variety of risks that undermine both productivity and profitability. These risks include unpredictable rainfall patterns, extended dry spells, rising temperatures, and increasing incidences of pest and disease outbreaks, particularly *Maruca vitrata* and *Callosobruchus maculatus* (Ibrahim, Shettima and Usman, 2019; Kamai Zakka and Abdulraheem, 2020).

These biotic and abiotic stressors, compounded by market price volatility, low access to formal insurance products, and weak infrastructural support systems, create a hostile operating environment for smallholder cowpea farmers (Joel *et al.*, 2025).

Furthermore, the post-harvest segment—dominated by informal processors, many of whom are women—is equally exposed to high levels of risk through poor storage infrastructure, susceptibility to pest damage, and the absence of standardized quality control systems (Maisule *et al.,* 2025). As a result, farmgate profits remain minimal, post-harvest losses are estimated to range between 15% and 30%, and producers struggle to maintain consistent supply to meet both local and export market demands (Ajayi, Fatunbi and Akinbamijo, 2020; Olomola, 2021).

Traditional risk management strategies employed by cowpea farmers and processors in Nigeria tend to be reactive and informal. These include diversified cropping, delayed planting, reliance on indigenous knowledge systems, and limited engagement with formal credit or insurance mechanisms (Ibrahim *et al.,* 2019 Olawumi *et al.,* 2025). While these strategies reflect a high degree of local adaptation, they are often insufficient in the face of increasingly erratic climatic patterns and volatile agricultural markets driven by global and regional trade disruptions. Additionally, smallholder cowpea producers frequently lack timely access to accurate meteorological data, pest forecasts, or market intelligence, which significantly limits their capacity to make informed decisions (Oyediji *et al.,* 2025). In this context, Artificial Intelligence (AI) has emerged globally as a potentially transformative tool for enhancing agricultural risk management by offering predictive, real-time, and data-rich support systems across the agricultural value chain. AI-driven systems are increasingly capable of leveraging large datasets ranging from satellite imagery and weather data to market trends and pest infestation records to generate actionable insights that could help farmers and processors anticipate risks and respond more effectively. For instance, AI models trained on historical weather patterns can now forecast drought conditions with considerable accuracy, while machine vision tools can identify early signs of pest infestation on leaves through smartphone applications (Kamilaris and Prenafeta-Boldú, 2018; Adebayo, Lawal and Alamu, 2022). In theory, the use of such AI tools could dramatically shift the paradigm of risk management from reactive coping to anticipatory planning. However, the real-world integration of AI into smallholder agricultural systems in Nigeria remains limited and faces a range of critical challenges (Oyediji *et al.,* 2024; Olawumi *et al.,* 2025).

The application of AI in agriculture, particularly in smallholder systems in sub-Saharan Africa, is constrained by several interrelated technological, socio-economic, and institutional barriers. First, the digital divide remains a significant obstacle. Many rural areas in Nigeria lack reliable internet connectivity, access to smartphones, or electricity infrastructure, all of which are foundational for AI-enabled platforms to function effectively (Barrett and Rose, 2022). Digital literacy among rural farmers and processors also remains low, further limiting the capacity of these stakeholders to utilize or even trust AI-driven tools.

Moreover, many existing AI tools in agriculture are designed for commercial agribusinesses or industrial-scale farms and are poorly adapted to the resource constraints and knowledge systems of smallholder farmers. For example, pest detection algorithms that require high-resolution imaging or cloud-based computing may be inaccessible to most farmers in rural northern Nigeria. Even where relevant AI tools are available, adoption remains low due to lack of trust, poor user experience, limited training, and the absence of intermediary support systems such as local extension agents equipped to interpret and translate AI-generated information (Hellin and Camacho, 2017; Lai-Solarin *et al.,* 2025). For cowpea processors, the post-harvest segment has received even less attention in AI research, despite its critical importance for food security and farmer incomes. Issues such as mold detection, storage optimization, and supply chain monitoring remain underdeveloped in the AI literature, further illustrating the narrow scope of current technological interventions (Sennuga *et al.,* 2025).

Given these constraints and the unique characteristics of cowpea farming and processing systems in Nigeria, there is an urgent need to better understand how AI technologies can interface with the specific risk experiences of smallholder actors across the value chain. Cowpea stakeholders are not a homogeneous group; they differ by gender, region, scale of operation, access to inputs, and level of formal education. Furthermore, the informal nature of many cowpea markets and the dominance of unregulated input systems introduce further complexity to risk prediction and mitigation. These factors necessitate a context-specific analysis of both the technological capabilities and the social dynamics that mediate AI adoption and effectiveness. As Nigeria moves forward with its digital agriculture agenda—articulated in the National Agricultural Technology and Innovation Policy (NATIP, 2021–2025)—there is a critical need to generate empirical evidence on how AI can serve not merely as a technological fix but as a support system that aligns with the everyday realities of rural farmers and processors. Addressing this knowledge gap is essential to ensure that AI-enabled agricultural systems are inclusive, relevant, and responsive to local needs, particularly in under-researched crops like cowpea that are vital for both economic resilience and nutritional security. This study aims to evaluate the interface between AI tools and the risk experiences of smallholder cowpea stakeholders in Nigeria. To accomplish this, the following objectives are put forward to:

i. Describe the socio-economic characteristics of smallholder cowpea farmers and processors in the study area.

ii. Assess the levels of awareness, accessibility, and patterns of adoption of AI-enabled technologies among smallholder cowpea stakeholders in the study area

iii. Examine the availability, functionality, and relevance of existing AI tools designed to address agricultural risks, with specific attention to their applicability within cowpea-based farming systems in the study area

iv. Analyze the socio-economic, demographic, and institutional factors influencing the adoption and effectiveness of AI applications for risk management in cowpea farming and processing in the study area.

v. Assess the challenges faced by smallholder cowpea farmers and processors in adopting AI for agricultural risk management in the study area.

II. LITERATURE REVIEW

2.1 Theoretical Framework:

2.1.1 Technology Acceptance Model (TAM):

The Technology Acceptance Model (TAM), developed by Davis (1989), serves as the primary theoretical foundation for this study. TAM is a widely used framework for explaining and predicting user behaviour in relation to new technologies. It is particularly relevant in understanding how individuals come to accept and use technological innovations, especially in contexts where adoption is influenced by perceptions of both utility and usability. In its original formulation, TAM posits that two key variables—Perceived Usefulness (PU) and Perceived Ease of Use (PEOU)—determine an individual's attitude toward using a given technology, which in turn influences their behavioural intention to use, and ultimately, their actual usage behaviour. PU refers to the degree to which a person believes that using a system will enhance their job performance, while PEOU refers to the degree to which the individual believes that using the system would be free of effort (Davis, 1989).

In the context of this study, TAM provides a structured lens for analyzing how smallholder cowpea farmers and processors in Nigeria evaluate and engage with Artificial Intelligence (AI) technologies aimed at agricultural risk management. These technologies may include mobile-based pest detection tools, AI-enhanced weather forecasting systems, price prediction platforms, and post-harvest monitoring applications. Understanding the adoption of such tools requires insight into how potential users perceive their effectiveness in mitigating risks and improving agricultural decision-making. If farmers or processors perceive AI tools as useful—for instance, in forecasting rainfall to optimize planting schedules or detecting pest threats early—they are more likely to adopt and integrate them into their routines. Conversely, if they view such technologies as difficult to understand or operate—particularly in low-literacy or low-connectivity settings—then even the most technically advanced tools may face resistance or underutilization. Hence, PU and PEOU are central to understanding the uptake of AI within smallholder contexts where digital literacy, trust in technology, and resource availability vary widely.

Importantly, applying TAM in this study allows for the empirical investigation of how AI tools are perceived across diverse segments of the cowpea value chain. It enables a comparison between different user groups—such as men and women, younger and older farmers, literate and non-literate users—and highlights the role of context in shaping technology adoption.

2.2 Conceptual Framework:

The conceptual framework for this study, exploring the relationship between the independent variables and the dependent variable (adoption of AI tools) being mediated by the intervening variables. The independent variables in this study are the core factors hypothesized to influence both the adoption of AI and its effectiveness in managing agricultural risk, and these include availability of ai tools, exposure to extension services and ICT platforms, socio-demographic characteristics and risk perception. The intervening variables are contextual factors that can mediate or moderate the relationship between independent and dependent variables. They include access to infrastructure, institutional support, trust and attitude toward technology, training and technical capacity, social networks and peer influence.

III. MATERIALS AND METHODS

3.1 Study Area:

Niger State, located in the North-Central geopolitical zone of Nigeria, serves as the study area for this research. It is the largest state in Nigeria by landmass, covering approximately 76,000 square kilometers, and shares boundaries with Kaduna, Kebbi, Kogi, Kwara, and the Federal Capital Territory (FCT), as well as the Republic of Benin to the west. The state is administratively divided into 25 local government areas (LGAs) and is characterized by a predominantly agrarian economy. According to the

National Population Commission (NPC, 2022), Niger State has an estimated population of over 6 million, with the majority living in rural areas and engaging in small-scale agricultural activities for both subsistence and commercial purposes. Niger State is particularly well-suited for a study of this nature due to its significant cowpea production, its vulnerability to agro-climatic risks, and the diverse agro-ecological and socio-economic characteristics found within its rural communities. In addition to its agro-ecological suitability, Niger State presents a compelling case for studying the adoption of artificial intelligence (AI) tools due to its mixed levels of rural infrastructure, varying access to extension services, and increasing exposure to digital agriculture initiatives. Despite growing efforts to modernize agriculture, smallholder cowpea farmers and processors in the state continue to face a variety of production and post-harvest risks. These include erratic rainfall, pest infestations (notably *Maruca vitrata* and *Callosobruchus maculatus*), storage losses, and price volatility, all of which contribute to income instability and food insecurity (Ajayi *et al*., 2020; Ibrahim *et al*., 2019). The state's farmers are often underserved by extension agents, poorly integrated into formal insurance schemes, and lack access to timely information and predictive analytics. However, recent efforts by the government and non-governmental actors—such as the deployment of mobile-based advisory systems and digital market platforms—signal growing interest in leveraging technology for rural transformation. As such, Niger State offers an ideal microcosm to examine the interface between AI-enabled technologies and agricultural risk management in smallholder systems.

3.2 Population of the Study and Research Design:

The population for this study comprises smallholder cowpea farmers and processors in selected local government areas of Niger State, Nigeria. These individuals are primarily engaged in cowpea cultivation and post-harvest processing, operating within informal or semi-formal value chains and exposed to a range of agricultural risks. The study adopts a mixed-methods research design, integrating both quantitative and qualitative approaches. Quantitative data will be collected through structured questionnaires to assess AI adoption, risk exposure, and socio-economic factors. Qualitative insights will be gathered via key informant interviews (KIIs) and focus group discussions (FGDs) with farmers, processors, extension agents, and technology providers. This design allows for triangulation of data, enhances reliability, and enables a contextualized understanding of how AI tools are perceived and utilized in managing agricultural risks among smallholder cowpea stakeholders.

3.3 Sample Size and Sampling Techniques:

This study adopted a multistage sampling technique to select 200 respondents, consisting of smallholder cowpea farmers and processors in six purposively selected LGAs of Niger State: Bida, Lavun, Gbako, Bosso, Shiroro, and Kontagora. These LGAs were chosen based on their significance in cowpea production and processing, vulnerability to agricultural risks, and varying exposure to agricultural innovations. In the second stage, 15 communities (2–3 per LGA) were randomly selected from lists provided by the Niger State Agricultural Development Project (NSADP). In the final stage, respondents were drawn from community registers and cooperative lists using systematic random sampling, ensuring inclusion across gender and age groups. Participants were selected from two categories: smallholder farmers (≤5 hectares) and processors (involved in threshing, drying, storage, or marketing). Sample allocation across LGAs was proportionate: Bida (40), Lavun (35), Gbako (30), Bosso (30), Shiroro (30), and Kontagora (35). Inclusion criteria required respondents to be active in cowpea farming or processing during the 2023/2024 season, aged 18 or above, residents for at least two years, and willing to provide informed consent. This approach ensured representativeness and enhanced the reliability of the findings.

3.4 Data Collection:

For this study, the primary data collection instrument was a structured questionnaire designed to gather comprehensive information from smallholder cowpea farmers and processors in Niger State. The questionnaire was tailored to capture data on agricultural risk exposure, perceptions of artificial intelligence (AI) tools, and technology adoption behaviour. Each questionnaire session lasted approximately one hour, allowing respondents adequate time to provide thoughtful and accurate responses. To ensure validity and reliability, the instrument was pre-tested through a pilot study involving a small group of cowpea stakeholders who were not part of the main sample. Feedback from the pilot enabled the research team to refine question wording, eliminate ambiguities, and improve the questionnaire's clarity and relevance to the study objectives. Trained enumerators administered the final version of the questionnaire in local languages where necessary, helping respondents understand the questions and respond accurately. This process ensured the collection of high-quality, contextually grounded data for analysis.

3.5 Data Analysis:

The data collected for this study were analyzed using a combination of descriptive and inferential statistical methods, tailored to address each of the study's specific objectives. Descriptive statistics such as frequencies, percentages, and means were employed to analyze Objective (i) and (ii). Objective (iii) was analyzed using a 4-point Likert scale (Strongly Agree to Strongly Disagree). To assess Objective (iv), a multiple regression analysis was used to estimate the relationships between the dependent and independent variables. For Objective (v), Kendall's Coefficient of Concordance (W) was used to rank and assess the level of agreement among respondents regarding the severity of identified challenges. All statistical analyses were conducted using SPSS (Statistical Package for the Social Sciences), Version 24, ensuring robust and systematic data handling.

3.6 Model Specification:

3.6.1 Model for Likert Scale Rating:

A 4-point Likert scale was employed to assess the perceived availability, functionality, and relevance of AI tools in managing agricultural risks, as outlined in Objective (iii) of the study. Respondents were presented with a list of AI-enabled technologies or functions (e.g., weather forecasting apps, pest detection tools, price prediction systems) and asked to indicate their level of agreement with statements regarding each tool's availability and usefulness in their farming or processing activities. The Likert scale was structured as follows:

- Strongly Agree (SA) – 4
- Agree (A) – 3
- Disagree (D) – 2
- Strongly Disagree (SD) – 1

The decision benchmark was set at 2.5, which served as the cut-off point for determining whether the responses indicated a generally positive or negative disposition. A mean score ≥ 2.5 was interpreted as a high level of positive perception, while a score < 2.5 reflected limited negative view.

To calculate the mean Likert score for each item, the following formula was used:

$$X_s = \frac{\sum fn}{Nr} \quad (1)$$

Where:

- X_s= Mean Likert score
- $\sum fn$ = Summation of the product of frequency and assigned Likert value
- f = Frequency of each Likert response (4, 3, 2, 1)
- n = Likert scale values (4, 3, 2, 1)
- Nr = Total number of respondents

3.6.2 Multiple Regression Model:

To address Objective (iv), a multiple linear regression model was employed to determine the extent to which various socio-economic, demographic, and institutional factors influence the adoption of AI tools for agricultural risk management. The model is specified as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + ... + \beta n X n + \varepsilon \quad (2)$$

Where:

- Y = Level of adoption/effectiveness of AI tools
- β_0 = Constant term
- $\beta_1 \ldots \beta n$ = Coefficients of explanatory variables

- $X_1 \ldots X_n$ = Independent variables (e.g., age, education, farm size, extension access, income, input access, farming experience)
- ε = Error term accounting for unexplained variation

3.6.3 Kendall's Coefficient of Concordance (*W*):

To address Objective (v)—which seeks to identify and rank the key challenges faced by smallholder cowpea farmers and processors in adopting AI tools for agricultural risk management—Kendall's Coefficient of Concordance (W) was employed.

The formula for calculating Kendall's Coefficient of Concordance is:

$$W = \frac{12\sum(R_i - \bar{R})^2}{m^2\,(n^3 - n)} \tag{3}$$

Where:

W = Kendall's Coefficient of Concordance

R_i = Sum of ranks for each challenge

$\bar{R}$= Mean of the ranks

m = Number of respondents

n = Number of ranked challenges

IV. RESULTS AND DISCUSSION

4.1 Socio-Economic Characteristics of Small-scale Cowpea Farmers and Processors:

The analysis showed that 62% of cowpea farmers were male, while 38% were female. This reflects the gendered division of labour in Nigerian agriculture, where men typically control land and production activities, and women participate more in post-harvest processing (Doss, 2018). Most respondents (75%) were between 31 and 60 years, with a mean age of 43.8 years. This suggests that cowpea farming is dominated by middle-aged adults who are economically active and possess valuable farming experience. Younger farmers (18–30) represented only 15% of the population, highlighting challenges such as limited land access, low profitability, or youth disinterest in farming, which aligns with findings from Akpan (2019) on youth disengagement in agriculture. A majority of respondents (77%) were married, while 13% were single and 10% widowed or divorced. Being married often implies larger household responsibilities and access to shared labour, which can influence farming intensity and technology adoption. Marital status is also associated with stability in agricultural enterprises and greater likelihood of cooperative membership and credit access, both of which support farm decision-making (Olawuyi and Ogunniyi, 2021).

About 53% of respondents had only primary or no formal education, while 47% attained secondary or tertiary education. Higher education levels tend to facilitate technology adoption due to improved literacy, better understanding of technical information, and increased confidence in using mobile-based advisory platforms (Adebayo *et al*., 2022). The average farming experience was 11.2 years, with 81% of farmers having more than five years of experience. Longer experience is typically associated with better problem-solving capacity and openness to technology adoption, as seasoned farmers are more capable of evaluating innovations for their relevance and utility (Ogundele and Okoruwa, 2019).

Farm sizes were small, with an average of 1.86 hectares. Most farmers (73%) cultivated between 1 and 5 hectares, while 25% operated on less than 1 hectare. Small farm size limits production output and may reduce motivation to invest in AI-based solutions perceived as costly or complex (Igbalajobi, Fashola and Yusuf, 2020). About 69% of the farmers belonged to cooperatives. Group membership is essential for accessing training, extension services, and input subsidies. Cooperatives play a crucial role in bridging the digital divide and improving access to risk management tools, particularly in areas underserved by public extension systems (Maguire-Rajpaul, Osabutey and Okon, 2021).

A total of 61% of farmers reported access to extension services. This access improves awareness and uptake of technologies by enhancing farmers' knowledge and reducing uncertainty. Farmers with regular contact with extension agents are more likely to be exposed to AI applications for climate forecasting or pest detection, consistent with studies by Agwu and Chah (2020) that highlight extension systems as a key enabler of innovation diffusion.

TABLE 1
SOCIO-ECONOMIC CHARACTERISTICS OF SMALL-SCALE COWPEA FARMERS AND PROCESSORS (n = 200)

Variable	Freq (n = 200)	Percent
Gender		
Male	124	62.0
Female	76	38.0
Marital status		
Single	26	13.0
Married	154	77.0
Widowed/Divorced	20	10.0
Educational level		
No formal education	42	21.0
Primary school	64	32.0
Secondary school	58	29.0
Tertiary education	36	18.0
Age (Mean = 43.8 yrs)		
18 – 30 years	30	15.0
31 – 45 years	86	43.0
46 – 60 years	64	32.0
Above 60	20	10.0
Years of farming Experience (Mean = 11.2 yrs)		
Less than 5 years	38	19.0
5 – 10 years	72	36.0
More than 10 years	90	45.0
Farm Size (Mean = 1.86 ha)		
Less than 1 hectare	50	25.0
1 – 2 hectares	96	48.0
2.1 – 5 hectares	54	27.0
Cooperative Membership		
Member	138	69.0
Non-member	62	31.0
Access to Extension Services		
Yes	122	61.0
No	78	39.0

Source: Field Survey, 2025

4.2 Awareness, Accessibility, and Patterns of Adoption of AI-Enabled Technologies among Smallholder Cowpea Stakeholders:

A total of 68% of farmers reported awareness of AI systems that offer weather-based planting and harvesting guidance. This suggests relatively high exposure to climate-smart digital innovations. Kamilaris and Prenafeta-Boldú (2018) noted that localized weather intelligence powered by AI enhances farm-level decision-making by reducing uncertainty, especially in areas like Niger State where rainfall is variable and climate risks are pronounced. The data in Table 2 revealed that 62% of respondents were aware of mobile-based AI applications that provide early warnings on pest and disease outbreaks. This reflects moderate exposure to AI-driven risk advisory tools. According to Adebayo *et al*. (2022), knowledge of AI-assisted diagnostic tools significantly improves farmers' capacity to anticipate and respond to biotic stress.

About 54% of farmers indicated awareness of AI platforms that predict market prices for cowpea. Such platforms help farmers make informed marketing decisions and avoid distress sales. Olomola (2021) emphasized that integrating AI into market systems allows smallholders to track trends and respond proactively, especially in informal market environments where price volatility is common and access to real-time data is often limited. About 53% of respondents rely on peer farmers or cooperative members for support in using AI tools. According to van Etten, Beza, Mittra and Agarwal (2019), community-based knowledge exchange is instrumental in scaling agricultural innovation, particularly when formal training systems are absent. Only 46% of respondents reported having accessed AI-based advisory services through mobile phones, radio programs, or digital apps. Barrett and Rose (2022) argue that technological availability does not guarantee usage, especially in rural areas constrained by low digital literacy, inadequate infrastructure, and limited access to smartphones or extension agents equipped with AI platforms.

Just 42% of respondents confirmed adopting at least one AI-enabled technology in their farming or post-harvest practices. This figure underscores a significant gap between awareness and practical use. Adoption decisions are often mediated by perceptions of risk, trust, and ease of use, as outlined in the Technology Acceptance Model (Davis, 1989). Only 38% of farmers reported receiving AI-generated information through extension agents or cooperative networks. This low figure indicates a weak linkage between AI systems and frontline advisory channels. Hellin and Camacho (2017) stressed that the success of digital agriculture depends on intermediaries who can contextualize and translate technical information for local use. Just 29% of respondents reported finding AI platforms easy to use for cowpea production activities. This suggests usability remains a barrier to adoption. Adebayo *et al*. (2022) similarly noted that limited user-friendly interfaces and language barriers reduce the accessibility of AI tools among low-literate farmers.

TABLE 2
AWARENESS, ACCESSIBILITY, AND PATTERNS OF ADOPTION OF AI-ENABLED TECHNOLOGIES AMONG SMALLHOLDER COWPEA STAKEHOLDERS (n = 200)

Statement	Frequency (f)	Percentage (%)
I am aware of mobile-based AI applications that provide early warnings for pest and disease outbreaks in cowpea fields.	124	62.0%
I have heard about AI-powered platforms that use weather forecasts to guide planting and harvesting decisions.	136	68.0%
I know about market information systems that use AI to predict cowpea price trends across different markets.	108	54.0%
I have personally accessed AI-based agricultural advisory tools via mobile phone, radio, or digital platforms.	92	46.0%
I have adopted at least one AI-enabled tool or service to support my farming or post-harvest decision-making.	84	42.0%
I regularly receive AI-generated alerts or recommendations through extension officers or cooperatives.	76	38.0%
I find it easy to use mobile or digital platforms that involve AI support for cowpea production activities.	58	29.0%
I rely on fellow farmers or cooperative members to explain or assist with AI-based farming tools when available.	106	53.0%

Source: Field Survey, 2025 **Multiple Responses**

4.3 Perceptions of the Availability, Functionality, and Relevance of AI Tools for Agricultural Risk Management in Cowpea Farming:

A majority of respondents (73%) agreed that AI-based weather forecasting tools are both available and useful for guiding planting and harvesting. This reflects a positive perception, supported by a mean score of 2.91. The reliability of weather prediction in cowpea farming is critical due to rainfall variability, and AI tools provide timely data to reduce exposure to climatic risks (Kamilaris and Prenafeta-Boldú, 2018). Respondents generally agreed (67%) that AI tools address core agricultural risks, including rainfall variability, pests, and market instability. The mean score of 2.81 supports the perception that AI applications are functionally aligned with smallholder needs. This finding aligns with Kamilaris and Prenafeta-Boldú (2018), who emphasize the strength of AI in managing multi-dimensional agricultural risks when backed by robust data sources.

Approximately 63% of respondents perceived AI-driven pest and disease detection tools as effective and accessible, with a mean of 2.76. This indicates broad recognition of their functionality in supporting real-time intervention during outbreaks.

Studies show AI-based image recognition and alert systems improve pest control efficiency (Adebayo *et al*., 2022). A total of 60% agreed that AI platforms are applicable to both production and post-harvest activities, with a mean score of 2.69. This indicates a favourable perception of the relevance of AI across the cowpea value chain. Adebayo *et al*. (2022) note that AI tools used in harvest prediction, storage monitoring, and market planning offer comprehensive support to farmers beyond field-level operations.

With 58% agreement and a mean score of 2.65, respondents acknowledged that AI-powered market price prediction platforms are useful in making informed sales decisions. Olomola (2021) highlights that price intelligence systems support better integration of smallholders into dynamic markets, enhancing income stability. Only 53% of farmers believed AI tools are tailored to the specific challenges of cowpea farming in their region, though the mean score of 2.57 remains slightly above the threshold. This suggests moderate confidence in localized relevance. According to van Etten *et al*. (2019), failure to contextualize digital advisory content often limits adoption and diminishes the perceived value of innovation at the farm level.

Only 47% of respondents believed existing AI tools are compatible with the mobile devices used by smallholder farmers, yielding a mean of 2.44. This suggests perceived barriers in accessibility due to software, device limitations, or connectivity. Barrett and Rose (2022) observed that limited infrastructure and device incompatibility restrict the adoption of digital tools in rural African contexts, despite increasing interest in AI innovations. Just 44% agreed that AI tools are easy to understand and use, resulting in a mean score of 2.38, below the acceptance threshold. This reflects low digital usability among smallholders. Limited ICT literacy and interface complexity may deter independent usage (Adebayo *et al*., 2022).

TABLE 3
PERCEPTIONS OF THE AVAILABILITY, FUNCTIONALITY, AND RELEVANCE OF AI TOOLS FOR AGRICULTURAL RISK MANAGEMENT IN COWPEA FARMING

Statements	Strongly Agree (4)	Agree (3)	Disagree (2)	Strongly Disagree (1)	Mean Score (Xs)	Decision
AI tools for weather forecasting are available and useful for making planting and harvesting decisions in cowpea farming.	52 (26.0%)	94 (47.0%)	38 (19.0%)	16 (8.0%)	2.91	ACCEPTED
AI-driven pest and disease detection tools are accessible and effective in supporting timely farm interventions.	46 (23.0%)	80 (40.0%)	54 (27.0%)	20 (10.0%)	2.76	ACCEPTED
AI market price prediction tools provide relevant and timely information to guide the sale of harvested cowpea.	40 (20.0%)	76 (38.0%)	58 (29.0%)	26 (13.0%)	2.65	ACCEPTED
AI-enabled advisory platforms are tailored to the specific challenges of cowpea farming systems in my region.	36 (18.0%)	70 (35.0%)	66 (33.0%)	28 (14.0%)	2.57	ACCEPTED
The AI tools I've encountered are easy to understand and operate without technical support.	28 (14.0%)	60 (30.0%)	72 (36.0%)	40 (20.0%)	2.38	REJECTED
Most AI technologies are compatible with the existing mobile phones and digital devices used by smallholder cowpea farmers.	32 (16.0%)	62 (31.0%)	68 (34.0%)	38 (19.0%)	2.44	REJECTED
AI tools address key risk areas in cowpea farming, including rainfall variability, pest outbreaks, and market volatility.	48 (24.0%)	86 (43.0%)	46 (23.0%)	20 (10.0%)	2.81	ACCEPTED
AI platforms are relevant and applicable to both farming and post-harvest decision-making in cowpea value chains.	42 (21.0%)	78 (39.0%)	56 (28.0%)	24 (12.0%)	2.69	ACCEPTED

Source: Field Survey, 2025

4.4 Factors Influencing Perception of AI Tools for Agricultural Risk Management:

The model summary in Table 4 indicates that the regression model explains 47.2% ($R^2 = 0.472$) of the variation in farmers' perception of AI tools for agricultural risk management, while the adjusted R^2 of 0.439 accounts for the number of predictors, confirming a good model fit. The F-statistic of 14.21 is statistically significant ($p < 0.001$), suggesting that the overall model is robust and that the combination of independent variables meaningfully predicts the dependent variable. Awareness of AI tools was highly significant at the 1% level (p = 0.000), with the strongest positive effect on perception. Farmers who know about AI technologies are more likely to value their relevance. According to Kamilaris and Prenafeta-Boldú (2018), awareness is the first stage of adoption, and without it, farmers may ignore or mistrust digital innovations designed to reduce risk and improve decisions. Extension contact was highly significant at the 1% level (p = 0.000), with a strong positive influence on AI perception. Access to extension services exposes farmers to innovations and facilitates understanding of their benefits. Agwu and Chah (2020) note that well-functioning extension systems are key channels for translating digital innovation into practice, especially when tools require contextualization and user training.

Gender was statistically significant at the 5% level, with male farmers more likely to have positive perceptions of AI tools (p = 0.018). This reflects gender disparities in technology exposure and digital access, where men often control resources and have higher engagement with extension services (Olawuyi and Ogunniyi, 2021). Age was weakly significant at the 10% level (p = 0.082), with a negative coefficient, suggesting that younger farmers are slightly more likely to perceive AI tools positively. This supports earlier findings by Akpan (2019), indicating that younger individuals are more tech-inclined, adaptable to innovation, and more engaged with mobile and digital platforms, which improves their receptiveness to emerging tools such as AI-based agricultural systems.

Education was significant at the 1% level (p = 0.010), showing a positive relationship with AI perception. According to Adebayo *et al*. (2022), farmers with formal education are more likely to explore digital farming tools and evaluate their utility, especially when exposed to training and information services. Farm size showed a positive and significant effect at the 5% level (p = 0.028), implying that farmers with larger plots tend to perceive AI tools more favourably. Larger farms may necessitate more planning and monitoring, increasing interest in tools that enhance efficiency. This finding is consistent with Igbalajobi *et al*. (2020), who report higher adoption of agricultural innovations among farmers with more land.

Membership in a cooperative was significant at the 5% level (p = 0.017), positively influencing AI perception. Maguire-Rajpaul *et al*. (2021) emphasize the role of farmer organizations in bridging the technology gap by offering training and improving trust in unfamiliar tools, especially in low-resource settings.

Access to credit was marginally significant at the 10% level (p = 0.051), indicating a modest positive influence on AI perception. Financial access enables farmers to invest in mobile devices, airtime, and training—all prerequisites for AI tool usage (Okpachu, Owoicho and Agom, 2021). Digital literacy was also significant at the 1% level (p = 0.005), affirming its critical role in shaping farmers' perception of AI. Digitally literate farmers are better equipped to understand, operate, and evaluate digital platforms (Barrett and Rose, 2022). Perceived risk level was not statistically significant (p = 0.464), indicating that general awareness of agricultural risks does not strongly influence AI perception. While risk sensitivity may drive interest in innovation, it may not translate into favourable attitudes unless paired with trust and usability (Ayanwale and Amusan, 2021).

Marital status was not statistically significant (p = 0.537), indicating no meaningful difference in AI perception between married and unmarried respondents. This aligns with findings by Doss (2018), where household status did not consistently predict technology attitudes. Farming experience was not significant (p = 0.111), suggesting that years in agriculture do not independently influence AI perception. As observed by Ogundele and Okoruwa (2019), experienced farmers may rely on traditional knowledge systems and exhibit cautious attitudes toward unfamiliar or data-driven tools like AI.

TABLE 4
MULTIPLE REGRESSION ANALYSIS OF FACTORS INFLUENCING PERCEPTION OF AI TOOLS FOR AGRICULTURAL RISK MANAGEMENT

Variable	Unstandardized Coeff. (B)	Standard error	t-value	Sig. (p-value)
Gender	0.218	0.091	2.396	0.018**
Age (Years)	-0.007	0.004	-1.750	0.082*
Marital Status	0.065	0.105	0.619	0.537
Educational Level	0.034	0.013	2.615	0.010***
Farming Experience (Years)	0.008	0.005	1.602	0.111
Farm Size (Hectares)	0.126	0.057	2.211	0.028**
Cooperative Membership	0.192	0.080	2.400	0.017**
Contact with Extension Agents	0.244	0.067	3.642	0.000***
Access to Credit (Yes = 1)	0.175	0.089	1.966	0.051*
Awareness of AI Tools (Yes = 1)	0.305	0.072	4.326	0.000***
Digital Literacy Score (0–10 scale)	0.060	0.021	2.857	0.005***
Perceived Risk Level (1–5 scale)	0.022	0.030	0.733	0.464
Number of Observation	200			
R-Squared	0.472			
Adjusted R-Squared	0.439			
-2 Log Likelihood	182.134			
F-statistic	14.21			

Note: ***, ** and * indicate significance at 1%, 5% and 10% probability level respectively

Source: Field Survey, 2025

4.5 Challenges Faced by Smallholder Cowpea Farmers and Processors in Adopting AI for Agricultural Risk Management:

The ranking of challenges using Kendall's Coefficient of Concordance ($W = 0.726$, $p < 0.001$) revealed strong and statistically significant agreement among respondents regarding the constraints they face in adopting AI tools. The highest-ranked challenge was the lack of digital literacy among farmers and processors, with a mean rank of 5.84. This highlights a major barrier, as effective engagement with AI platforms requires basic ICT skills. Closely following was the poor internet and mobile network infrastructure in rural areas (mean = 5.62), which limits access to real-time AI applications such as weather forecasting, market prediction, and pest alerts. The high cost of digital devices and data plans was also a top concern (mean = 5.38), reflecting affordability issues for smallholders operating on tight margins. Additionally, limited awareness of existing AI tools (mean = 4.97) and lack of training or support (mean = 4.81) further restrict adoption. These findings align with studies by Adebayo *et al*. (2022) and Barrett and Rose (2022), who noted that technology exposure and support systems are critical for digital inclusion in agriculture.

Lower-ranked but still significant were language barriers and complex user interfaces (mean = 4.29), low trust in AI-generated information (mean = 3.92), and poor integration of AI into existing extension services (mean = 3.17). These institutional and socio-cultural factors emphasize that adoption is not just a technical issue, but one deeply embedded in the realities of rural information systems and farmer experience.

TABLE 5
CHALLENGES FACED BY FARMERS LIMITING BIOTECHNOLOGY ADOPTION USING KENDALL'S COEFFICIENT OF CONCORDANCE

Challenges	Mean Rank	Rank
Most farmers and processors lack the digital literacy or skills required to operate AI-based platforms or interpret AI-generated data.	5.84	1st
Internet connectivity and mobile network coverage are poor or completely unavailable in many rural farming communities.	5.62	2nd
The cost of smartphones, data plans, and other digital tools required to access AI platforms is too high for most smallholders.	5.38	3rd
Many smallholder farmers and processors are unaware of existing AI tools or platforms available for agricultural risk management.	4.97	4th
There is limited access to practical training and technical support on how to use AI tools effectively in farming or processing.	4.81	5th
Most AI tools are not developed in local languages, and their interfaces are difficult for farmers with low literacy levels to use.	4.29	6th
Some farmers do not trust the accuracy or usefulness of AI-generated advice compared to traditional knowledge and local practices.	3.92	7th
Existing agricultural extension systems are weakly integrated with AI platforms, limiting their ability to disseminate such tools.	3.17	8th
Kendall's Coefficient of Concordance (W) Summary Kendall's W (calculated) = 0.726 Chi-Square (χ^2) = 101.64 Degrees of Freedom (df) = 7 Significance level (p) = 0.000		

Source: Field Survey, 2025

V. CONCLUSION AND RECOMMENDATIONS

This study investigated the intersection of artificial intelligence (AI) and agricultural risk management among smallholder cowpea farmers and processors in Niger State, Nigeria. The analysis revealed a predominantly male farming population (62%), with most respondents aged 31–45 years (43%) and married (77%). Education levels were modest, as 47% had only primary or no formal education. The average farm size was 1.86 hectares, and most respondents (69%) were cooperative members, while 61% had access to extension services—highlighting moderate levels of institutional support.

Awareness of AI technologies was relatively high: 68% of respondents were aware of AI tools for weather forecasting, 62% for pest and disease alerts, and 54% for market price prediction. However, usage levels were lower—only 42% had used any AI-enabled tool, 46% had accessed digital platforms, and just 29% found them easy to use. This points to a gap between awareness and actual adoption, shaped by accessibility and usability constraints. Perceptions of AI tool functionality and relevance were mixed. Weather forecasting tools received the highest mean score (2.91), followed by pest detection (2.76), market prediction (2.65), and risk mitigation applications (2.81), all exceeding the 2.5 threshold for positive perception. In contrast, ease of use (2.38) and device compatibility (2.44) scored below the threshold, reflecting ongoing barriers related to user interface and technological fit.

Regression analysis identified several statistically significant predictors of AI perception. Educational attainment, extension contact, digital literacy, and awareness of AI tools were highly significant at the 1% level. Gender, farm size, and cooperative membership were significant at the 5% level, while age and access to credit showed weak significance (10%). Marital status, farming experience, and perceived risk level were not statistically significant, suggesting that familiarity with risk does not automatically translate into AI engagement. A Kendall's Coefficient of Concordance ($W = 0.726$, $p < 0.001$) revealed strong agreement among respondents on the key challenges to AI adoption. These included low digital literacy (mean rank = 5.84), poor internet infrastructure (5.62), high costs of digital tools (5.38), and limited awareness of available AI resources (4.97). Other barriers involved inadequate training, language and interface limitations, distrust of AI-generated advice, and weak integration with traditional extension systems.

Based on the findings of the study, here are recommendations, derived from the data and analysis:

1. Given that limited digital literacy was the top-ranked barrier (mean rank = 5.84), government agencies, NGOs, and private sector actors should implement localized digital literacy programs. These should target smallholder farmers and processors, especially women and older individuals, to build basic ICT skills required to access and operate AI-enabled agricultural tools effectively.
2. Poor internet and mobile network coverage (mean rank = 5.62) significantly limits AI accessibility. Partnerships between government and telecom providers should prioritize the expansion of affordable internet connectivity and mobile network coverage in rural cowpea-producing areas to enable reliable access to AI platforms and digital advisory services.
3. High cost of smartphones, data, and digital tools (mean rank = 5.38) remains a major constraint. Digital inclusion initiatives should incorporate targeted subsidies or financing schemes (e.g., pay-as-you-go models) to make smartphones and AI-enabled applications more affordable and accessible to resource-constrained farmers.
4. Findings indicated low scores for ease of use (mean = 2.38) and device compatibility (mean = 2.44). Developers should prioritize user-centered design by simplifying AI interfaces, incorporating local languages, and ensuring compatibility with basic mobile phones to meet the needs of low-literate users.

Extension contact was a key predictor of AI perception (p = 0.000), yet weak integration with AI tools was a noted challenge. Extension systems should be upgraded to include AI training modules and tools, enabling agents to serve as digital intermediaries and bridge knowledge gaps in smallholder communities.

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Adoption of System of Rice Intensification (SRI) Methodology among Rice Farmers in Nasarawa State, Nigeria

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Abstract— *The research assessed farmers adoption of system of rice intensification (SRI) in Nasarawa State, Nigeria. The specific objectives of the study were to: describe the socioeconomic characteristics of SRI practitioners among rice farmers, investigated their awareness of SRI, evaluated their adherence to recommended SRI practices, explored factors influencing adoption, and identified barriers hindering adoption. A multi-stage sampling method was used to survey 300 participants. Data were collected using questionnaire and data obtained were analyzed using descriptive statistics and logit regression were employed to achieve these objectives. Results indicated that the majority of SRI practitioners were male, averaging around 45 years old, and typically lived in households with approximately (9) nine members. Findings also showed widespread awareness of nursery planting, high familiarity with manual weeding, and the use of organic fertilizers. Regarding adoption, practices such as nursery planting, transplanting young seedlings at three weeks old, and irrigation were commonly implemented. Logit regression analysis highlighted significant positive influences of gender (P<0.01) and education level (P<0.01) on SRI adoption. The primary barrier identified was the high cost of labor, which significantly deterred farmers from adopting SRI. The study concluded that the socioeconomic characteristics of farmers play a crucial role in their adoption of SRI in Nasarawa State. Recommendations included initiatives to mitigate labor costs and strengthen extension services to provide ongoing technical support and guidance on SRI practices.*

Keywords— Adoption, rice, intensification, methodology, farmers.

I. INTRODUCTION

Rice is a crucial cereal crop cultivated across diverse climatic zones worldwide, serving as the primary dietary staple for nearly half of the global population. It accounts for approximately one-third of the world's cereal cultivation and contributes significantly to caloric intake, ranging between 35% and 60% for about 2.7 billion individuals (Tayefe, Gerayzade, Amiri & Zade, 2014). In Nigeria, rice has increasingly become a vital component of the national diet and is now regarded as both a staple food and a major source of calories. Traditionally, Nigerian farmers have predominantly cultivated lowland rice due to its ecological compatibility. However, in recent years, actual production levels have fallen below potential, largely due to inefficient resource use and suboptimal practices. In response, the Nigerian government has implemented various initiatives aimed at transforming rice farming from subsistence-based operations to commercial enterprises. These include the provision of improved inputs and the establishment of Public-Private Partnership (PPP) frameworks to enhance agricultural productivity (Tayefe *et al.,* 2014).

Rice consumption in Nigeria has risen dramatically, growing at an annual rate of approximately 10%. It has become the predominant staple food among the country's population of over 200 million people (Terwase & Madu, 2014). Yet, domestic production has not kept pace with rising demand, leading to a significant gap between consumption and local supply (Omofonmwan & Kadiri, 2017). To bridge this gap, government institutions, Community-Based Organizations (CBOs), and Non-Governmental Organizations (NGOs) have intensified efforts to mobilize and train rice farmers in improved agronomic practices. One such innovation is the System of Rice Intensification (SRI), which has been promoted and demonstrated across the country as a viable strategy for enhancing rice productivity and achieving self-sufficiency.

SRI is an agronomic methodology aimed at improving the productivity of irrigated rice through optimized management of soil, water, nutrients, and plant spacing. The method involves transplanting young seedlings at wider intervals and practicing alternate wetting and drying (AWD), rather than continuous flooding, to stimulate better root growth and plant vigor (Fernandes & Uphoff, 2015). This approach was originally developed in Madagascar in the 1980s by Father Henri de Laulanié, with the objective of establishing sustainable farming systems that enhance productivity while minimizing input costs and conserving water resources (Zotoglo, 2017). Compared to traditional practices, SRI has proven to be more resource-efficient and environmentally sustainable. For example, while conventional broadcasting methods require 100 kg of seeds per hectare and direct planting requires 30–60 kg, SRI only uses 4–10 kg of seeds per hectare, substantially reducing input costs and labor demands (Randriamiharisoa, Barison & Uphoff, 2016).

In Nigeria, various public and community-based initiatives have supported the dissemination and demonstration of SRI practices, with the broader goal of achieving national rice self-sufficiency. However, adoption rates among rural farmers remain low, and rice yields and incomes are often still below levels recorded two decades ago. Several barriers to adoption persist, including poor dissemination of innovation and limited uptake of recommended practices. Farmers are generally more likely to adopt new technologies if they are simple, offer comparative advantages, are compatible with existing practices, and are both accessible and affordable (Bawa & Ani, 2014). In Nasarawa State, agencies such as the Commercial Agriculture Development Project (CADP), Fadama III Project, and the IFAD/FGN/Community-Based Natural Resource Management Programme (CBNRMP) have been active in promoting rice production, including SRI techniques. Despite these interventions, many farmers in the region remain economically vulnerable, and the overall awareness and adoption of SRI remain unclear. Therefore, this study was designed to assess the extent of adoption of the System of Rice Intensification (SRI) among rice farmers in Nasarawa State, Nigeria.

1.1 Objectives of the Study:

The broad objective of this study is to assess the level of adoption of the System of Rice Intensification (SRI) among rice farmers in Nasarawa State, Nigeria.

The specific objectives are to:

a) Describe the socio-economic characteristics of rice farmers practicing the System of Rice Intensification(SRI);
b) Assess the level of awareness of SRI among rice farmers in the study area;
c) Evaluate the extent to which rice farmers have adopted and adhered to the recommended SRI practices;
d) Determine the factors influencing the adoption of SRI among rice farmers in the study area;
e) Identify the constraints affecting the adoption of SRI among rice farmers in the study area;
f) Examine the sources of information available to farmers on SRI practices.

1.2 Hypotheses of the Study:

The study was guided by the following null hypotheses:

- **H_{01}:** There is no significant relationship between the socio-economic characteristics of rice farmers and their adoption of the System of Rice Intensification (SRI).
- **H_{02}:** There is no significant relationship between the use of SRI-recommended practices and the factors influencing adoption.

II. MATERIALS AND METHODS

2.1 Study Area:

The study was conducted in Nasarawa State, located in North Central Nigeria. Created in 1996 from the western part of Plateau State, Nasarawa is bordered by Taraba and Plateau states to the east, Kaduna State to the north, Benue and Kogi states to the south, and the Federal Capital Territory (FCT) to the west. The state comprises thirteen local government areas, with Lafia serving as the capital and Karu Urban Area as a key economic hub. As of 2025, the state has an estimated population of 3.1 million (NPC, 2025). Nasarawa's landscape features the tropical Guinean forest–savanna mosaic, with significant geographical features like the River Benue and a portion of the Jos Plateau. It is home to a diverse mix of ethnic groups such as the Koro, Eggon, Mada, Fulani, Hausa, Tiv, and Alago, with Islam, Christianity, and traditional religions practiced widely (NADP, 2010).

Historically, Nasarawa underwent multiple administrative transformations from incorporation into the Sokoto Caliphate during the Fulani jihad, to British colonial rule under the Northern Nigeria Protectorate, and through various post-independence state reconfigurations, until it became a distinct state in 1996. Economically, it is endowed with abundant mineral resources, including gold, marble, barite, gypsum, and kaolin (NASIDA, 2023). Despite this mineral wealth, agriculture remains the mainstay of the population, with key crops including rice, yam, cassava, cowpea, and groundnut.

Nasarawa is one of Nigeria's leading rice-producing states. From 2003 to 2008, it recorded an estimated rice production capacity of 655,000 metric tons per hectare. Between 2007 and 2014, about 642.16 hectares produced roughly 1.45 million metric tons of rice (NADP, 2010; NAERLS, 2014). The state government is committed to enhancing the agricultural value chain, with a focus on rice, sesame, and ginger, as well as investing in aquaculture, forestry, and livestock farming. These initiatives are aimed at fostering climate-resilient, market-oriented agricultural development (NASIDA, 2023).

2.2 Sampling Procedure and Sample Size:

The study employed a multi-stage sampling technique. The first stage involved the purposive selection of the Southern Agricultural Development Programme (ADP) zone out of the three ADP zones in Nasarawa State, as it is the largest rice-producing area and has been introduced to SRI practices. In the second stage, all ten (10) extension blocks within the Southern ADP zone were purposively selected to capture the full range of rice farming activities and ensure that no major rice-producing block was excluded from the study. The third stage involved the use of stratified random sampling to draw respondents proportionately from each of the ten blocks. A sampling fraction of 10% was applied to the total number of registered rice farmers (3,049) within the zone, resulting in the random selection of 306 farmers for the study.

2.3 Data Collection and Analysis:

Data for the study were collected from primary sources using a well-structured questionnaire that included both open- and close-ended questions. The instrument was vetted by experts from the Department of Agricultural Extension and Rural Sociology, University of Abuja, to ensure validity and clarity. Following this, the questionnaires were administered to respondents with the assistance of trained enumerators from the Nasarawa State chapter of the Rice Farmers Association of Nigeria (RIFAN). The questionnaire was divided into four sections, each addressing a specific aspect of the study. Both descriptive and inferential statistical tools were used for data analysis. Descriptive statistics such as frequency, percentages, means, and standard deviations were used to summarize the demographic characteristics and general trends in SRI awareness and practices. Adoption and extent of use of specific SRI practices were analyzed using a 4-point Likert scale: Always = 3, Often = 2, Rarely = 1, and Never = 0. Inferential statistics including logistic regression model was employed to identify the factors influencing the adoption of SRI. Principal Component Analysis (PCA) was used to identify and categorize the major constraints to SRI adoption by reducing complex variables into core components.

III. RESULTS AND DISCUSSION

3.1 Socioeconomic Characteristics of Rice Farmers Practicing SRI in the Study Area:

The socioeconomic characteristics of rice farmers practicing the System of Rice Intensification (SRI) in the study area are summarized in Table 1. The data revealed that 51% of the SRI rice farmers were men, while 49% were women. This near-equal gender distribution suggests that SRI practices are accessible and not perceived as overly labor-intensive or gender-exclusive. This aligns with FAO (2022), which emphasizes the potential of inclusive agricultural innovations to bridge gender gaps. Nonetheless, the slight male predominance may reflect existing gender disparities in access to agricultural resources and decision-making power, consistent with observations by the World Bank (2021).

In terms of age distribution, the majority of farmers (40%) were aged between 41 and 50 years, followed by 25.33% aged 51 and above, 21% aged 20–30, and 13.67% aged 31–40. The mean age was approximately 45 years, indicating that middle-aged farmers dominate the adoption of SRI. This group is typically more receptive to new technologies, balancing accumulated farming experience with the physical ability to manage labor-intensive practices. Rahman, Alam & Haque (2021) supported this view, stating that middle-aged farmers are more open to innovations that offer productivity gains and long-term sustainability.

Regarding marital status, 46% of the respondents were married. This demographic is often associated with higher investment motivation in sustainable practices to secure family welfare, as highlighted by Rahman *et al.*, (2021). Kumar *et al.*, (2020) also noted that married farmers tend to take calculated risks for the benefit of household stability. The remaining farmers were separated (17.33%), widowed (15%), divorced (13.67%), and single (8%).

Education levels among SRI farmers showed that 49% had attained secondary education, 42% pre-secondary, 9% primary education, and only 1.43% had no formal education. This distribution reinforces the importance of education in the adoption of modern agricultural technologies. Educated farmers are more likely to understand and apply technical knowledge associated with SRI practices, as affirmed by (Manda, Alene, Gardebroek, Kassie and Tembo, 2021).

Household size data indicated that 44.67% of the respondents had 6–10 members, 35.33% had 11–15 members, and 20% had 1–5 members. With an average household size of nine persons, the availability of family labor likely supports the implementation of labor-demanding practices associated with SRI. Kassie, Teklewold, Jaleta, Marenya and Erenstein (2020) noted that larger households have an advantage in adopting such practices due to labor availability. In terms of farming experience, 49% of SRI farmers had 11–21 years of rice farming experience, followed by 24% with 22–32 years, 26.33% with 1–10 years, and 0.67% with over 33 years. The average farming experience was about seven years. Experience plays a critical role in decision-making and the adoption of innovations, with Manda *et al.*, (2021) and Wainaina, Tongruksawattana, and Qaim (2022) highlighting that experienced farmers are more adept at evaluating and implementing new practices.

Lastly, 59.33% of farmers reported annual earnings between ₦1,801,000, and the average farm size was 1.38 hectares. This income level and limited landholding suggest that SRI is particularly suited to smallholder farmers, who often seek innovations that increase productivity and profitability on small plots (Abro, Alemu & Hanjra, 2022).

TABLE 1
FREQUENCY DISTRIBUTION OF SOCIOECONOMIC CHARACTERISTICS OF FARMERS

Variables	Frequency	Percentage	Mean
Sex			
Male	153	51.00	
Female	147	49.00	
Age			44.56 years
20 – 30	63	21.00	
31 – 40	41	13.67	
41 – 50	120	40.00	
≥ 51	76	25.33	
Marital Status			
Single	24	8.00	
Married	138	46.00	
Divorced	41	13.67	
Widowed	45	15.00	
Separated	52	17.33	
Level of Education			
Primary Education	27	9.00	
Secondary Education	147	49.00	
Post-Secondary Education	126	42.00	
Household Size			9 persons
1 – 5	60	20.00	
6 – 10	134	44.67	
11 – 15	106	35.33	
Rice Farming Experience			7.31 years
1 – 10	79	26.33	
11 – 21	147	49.00	
22 – 32	72	24.00	
≥ 33	2	0.67	
Annual Income			₦220,700.00
₦1,000,000 – ₦1,800,000	68	22.67	
₦1,801,000 – ₦2,601,000	178	59.33	
₦2,602,000 – ₦3,402,000	54	18.00	
Rice Farm Size			1.38 hectares
0 – 1.5	210	70.00	
1.6 – 3.1	73	24.33	
≥ 3.2	17	5.67	
Total	**300**	**100**	

Source: Field survey, 2024

3.2 Awareness of SRI Practices among Rice Farmers:

The data from Table 2, which presents the levels of awareness of System of Rice Intensification (SRI) practices among rice farmers, provides essential insights into the factors influencing the adoption of SRI in the study area. Awareness remains a crucial precursor in the technology adoption continuum, as farmers must first become knowledgeable about specific practices before evaluating and applying them.

The findings indicate very high levels of awareness for certain components of SRI. Notably, 98.33% of the farmers were aware of nursery planting, 90.33% were familiar with manual weeding, and 83.67% acknowledged the use of organic fertilizers. These figures suggest that these practices have already been integrated into the local farming systems, likely due to their alignment with traditional agricultural methods. As Kassie *et al.*, (2020) and Melesse *et al.*, (2021) argue, practices that are simple and contextually relevant tend to enjoy wider diffusion and acceptance among smallholder farmers.

In contrast, awareness of more technical or distinctively SRI-specific practices is considerably lower. Only 61.33% of farmers were aware of transplanting younger seedlings aged 10–15 days, while an even lower proportion (42.33%) were familiar with the recommended 25 × 25 cm seedling spacing. These practices are vital for realizing SRI's productivity potential, as they contribute to optimal plant growth and resource utilization. Manda *et al.*, (2021) suggest that the limited awareness of such practices may be attributed to the complexity of the techniques or insufficient extension support that hinders effective dissemination.

Moreover, although 76.33% of farmers were aware of intermittent irrigation as an essential element of SRI nearly a quarter remained unaware of this core practice. Given that water management is central to the efficiency and ecological sustainability of SRI, this gap in awareness could significantly impact adoption outcomes. As Abro *et al.*, (2022) point out, inconsistent or improper water regulation undermines the benefits of SRI, particularly in contexts where water resources are becoming increasingly scarce. The observed variation in awareness levels across SRI components highlights the need for targeted education and farmer support, focusing on the less understood yet crucial elements of the system.

TABLE 2
LEVEL OF AWARENESS OF SRI PRACTICES AMONG RICE FARMERS IN THE STUDY AREA

Practices	Aware (%)	Not Aware (%)	Total
Nursery planting	98.33	1.67	100
Transplanting of young seedlings at 10-15days old	61.33	38.67	100
Spacing 25cm – 25cm apart	42.33	57.67	100
Use of organic fertiliser	83.67	16.33	100
Manual weeding	90.33	9.67	100
Irrigation (application of water intermittently i.e control of water)	76.33	23.67	100

Multiple-choice Response Recorded

Source: Field survey, 2024.

3.3 The Adoption and Extent to Which Rice Farmers Followed the Recommended Practice of SRI:

The adoption and extent to which rice farmers followed the recommended practices of the System of Rice Intensification (SRI) are presented in Table 3. The results reveal varying degrees of compliance with SRI principles, indicating that while some practices are regularly implemented, others are adopted less consistently. This pattern suggests that many farmers engage in partial adoption of SRI, potentially limiting the overall effectiveness of the system. Among the practices assessed, nursery planting recorded the highest mean score (3.55), implying that farmers "always" adhere to this component. This consistency may be attributed to the simplicity and familiarity of nursery planting within traditional farming systems, requiring minimal technical skills or inputs. Its widespread use underscores the potential for integrating low-barrier practices into smallholder farming contexts.

Other practices such as transplanting young seedlings at 10–15 days old (mean = 3.14), the use of organic fertilizer (3.19), manual weeding (3.15), and intermittent irrigation (3.19) were generally followed "often." Although adoption levels are relatively high, they fall short of full compliance, which can undermine the system's potential. Timely transplanting is critical for yield maximization, and irregular implementation may affect results (Manda *et al.,* 2021). Similarly, intermittent irrigation, central to SRI's water-saving and plant health objectives, requires precision; its inconsistent application reflects challenges such as limited knowledge, labor availability, or access to water infrastructure (Hailu, Tegegne & Belay, 2022). Spacing seedlings 25 × 25 cm apart received the lowest mean score (2.65), indicating irregular adherence. Yet, this practice is essential for reducing inter-plant competition and optimizing nutrient uptake and light exposure. The low compliance rate may be due to the technical difficulty of maintaining uniform spacing or limited training on its importance. Addressing these gaps is vital for achieving the full agronomic potential of SRI.

TABLE 3
RESULT OF THE ADOPTION AND EXTENT TO WHICH RICE FARMERS FOLLOWED THE RECOMMENDED PRACTICE OF SRI

Recommended practices	Always (3)	Often (2)	Rarely (1)	Never (0)	Total	Mean	Remark
Nursery planting	668 (62.66)	396 (37.15)	2 (0.19)	0 (0.00)	1066	3.55	Always
Transplanting of young seedlings at 10 -15days old	352 (37.41)	513 (54.52)	70 (7.44)	6 (0.64)	941	3.14	Often
Spacing 25cm – 25cm apart	236 (29.72)	363 (45.72)	150 (18.89)	45 (5.67)	794	2.65	Often
Use of organic fertiliser	344 (35.91)	564 (58.87)	48 (5.01)	2 (0.21)	958	3.19	Often
Manual weeding	348 (36.86)	516 (54.66)	78 (8.26)	2 (0.21)	944	3.15	Often
Irrigation (application of water intermittently i.e control of water)	392 (40.96)	483 (50.47)	82 (8.57)	0 (0.00)	957	3.19	Often

Source: Field survey, 2024

Table 4 presents the sources of information through which farmers learned about the System of Rice Intensification (SRI), underscoring the pivotal role of information dissemination in shaping agricultural innovation adoption. Social media emerged as the most significant source (32.18%), suggesting its growing influence in agricultural knowledge transfer. With features such as real-time updates, broad accessibility, and user interactivity, social media platforms are proving particularly effective for spreading awareness of SRI practices. This trend aligns with findings by Abro *et al.,* (2022), who noted that digital technologies increasingly enhance access to agricultural knowledge, especially among younger and tech-savvy farmers.

Extension agents were the second most reported source (24.39%), reaffirming the relevance of traditional extension systems in knowledge dissemination. Their role remains critical, as they provide localized, experience-based advice and often facilitate on-site demonstrations. As trusted liaisons between research and rural communities, extension agents continue to play an important part in promoting practices like SRI.

Traditional media radio (12.52%), television (9.20%), and newspapers (10.73%) remain part of the information ecosystem, though less dominant. Radio, in particular, retains value in rural areas due to its affordability and reach. However, the relatively lower reliance on these outlets compared to social media may reflect a shift toward digital communication, likely influenced by the growing accessibility of smartphones and internet connectivity (Wainaina *et al.,* 2022). Friends and peer networks (10.98%) also played a notable role, highlighting the importance of informal, community-based learning in the adoption process. Peer influence and firsthand testimonials often drive trust and willingness to adopt innovations like SRI.

TABLE 4
SOURCE OF INFORMATION ON SRI.

Source of Information	Frequency*	Percentage (%)
Radio	98	12.52
Extension Agent	191	24.39
Television	72	9.20
Friend	86	10.98
Social medial	252	32.18
Newspaper	84	10.73
Total	**783**	**100**

*Multiple-choice Response Recorded

Source: Field survey, 2024.

3.4 Factors Influencing the Adoption of the System of Rice Intensification (SRI):

To examine the factors influencing the adoption of the System of Rice Intensification (SRI) among rice farmers in the study area, a binary logistic regression model was employed. The dependent variable was the adoption status of SRI, while the explanatory variables included age, sex, education level, marital status, household size, rice farm size, farming experience, and annual income. The results of the regression analysis are presented in Table 5. The model produced a Log-likelihood value of -162.3034 and a Wald chi-square value of 53.20, which is statistically significant at the 1% level. This indicates that the model fits the data well and that the explanatory variables jointly influence the likelihood of adopting SRI.

Out of the eight variables considered, six were found to significantly influence the adoption of SRI. These include age, sex, education level, household size, farm size, and annual income while farm experience and marital status were not significant. Consequently, the null hypothesis stating that there is no significant relationship between farmers' socioeconomic characteristics and SRI adoption is rejected.

Age was negatively associated with SRI adoption and was significant at the 10% level (coefficient = -0.0324), indicating that younger farmers are less likely to adopt SRI. Although younger individuals are typically more open to innovation, this result may reflect barriers like digital literacy or conservative tendencies among older farmers (Oladele, Akinwale & Ajani, 2022). Sex also significantly influenced adoption (coefficient = 0.9426, $p < 0.01$), with male farmers more likely to adopt SRI. As noted by FAO (2023), women often face structural barriers such as limited access to resources, cultural restrictions, and lower digital literacy, which impede their participation in innovative practices.

Education level had a strong positive effect on adoption (coefficient = 0.9426, $p < 0.01$). Educated farmers are better equipped to understand, access, and implement the knowledge-intensive components of SRI. Manda *et al.,* (2021) also observed that education enhances a farmer's likelihood of engaging with training and extension services, which are critical for adopting technical innovations like SRI. Household size, on the other hand, had a significant negative effect (coefficient = -0.5898, $p < 0.01$), suggesting that while larger families offer more potential labour, internal competition for time and resources may reduce the likelihood of adopting labour-intensive systems like SRI.

Rice farm size was positively related to adoption (coefficient = 0.8413, $p < 0.01$), indicating that farmers with larger plots are more likely to adopt SRI. Larger holdings allow for cost distribution and may offer better economies of scale, increasing the attractiveness of investing in a new system. Lastly, annual income also showed a positive and significant relationship with adoption (coefficient = -4.53e-06, $p < 0.05$). This indicates that wealthier farmers are more capable of absorbing the initial costs and risks associated with adopting new technologies like SRI, corroborating the findings of Wainaina *et al.,* (2022).

TABLE 5
FACTORS INFLUENCING THE ADOPTION OF SRI AMONG RICE FARMERS

Variables	Parameters	Coefficient	Robust Std. Err	z-value
ICT Specific Variables				
Age (X_1)	β_1	-0.0324	0.0192	-1.69*
Sex (X_2)	β_2	0.9426	0.2859	3.30***
Level of Education (X_3)	β_3	1.1283	0.3514	3.21***
Marital Status (X_4)	β_4	0.0504	0.1516	0.33
Household Size (X_5)	β_5	-0.5898	0.2091	-2.82***
Rice Farm Size (X_6)	β_6	0.8413	0.1437	5.86***
Rice Farming Experience (X_7)	β_7	0.0087	0.0322	0.27
Annual Income (X_8)	β_8	-4.53e-06	1.89e-06	-2.39**
Constant	β_0	-1.2260	0.8282	-1.48
Diagnostics Statistics				
Pseudo R-Square	-162.3034			
Wald Chi-Square (8)	53.20			
Prob > Chi-Square	0.0000			
Observation	300			

*** = significance at 1%, ** = significance @ 5% and * = significance @ 10%.

Source: Field survey, 2024

3.5 Constraints to the Adoption of the System of Rice Intensification (SRI) Among Rice Farmers:

The constraints to adopting the System of Rice Intensification (SRI) among rice farmers in the study area are presented in Table 6. The results reveal a number of significant challenges that hinder the widespread adoption of SRI practices, despite their potential for enhancing productivity and sustainability. Foremost among these is the high cost of labour. As a labour-intensive methodology, SRI demands substantial manual input for transplanting young seedlings, maintaining wider plant spacing, and engaging in regular manual weeding. In areas where labour is either scarce or expensive, these requirements become a major barrier, especially for smallholder farmers with limited resources (Tadesse, Azam-Ali & Kedir, 2023).

Transportation costs emerged as another substantial constraint. Farmers must often transport both inputs (such as organic fertilisers) and harvested produce, a process that becomes costlier with poor rural infrastructure. These elevated costs can make the adoption of SRI practices less appealing, as farmers are deterred by the additional financial burden associated with logistics (Hailu *et al.,* 2022; Mwakaje, 2023). Similarly, inadequate financial resources limit the capacity of farmers to invest in necessary inputs like organic fertilisers and herbicides. Smallholder farmers, in particular, may lack access to credit or institutional support, making it difficult to adopt practices whose financial benefits accrue only in the longer term (Mekonnen, Noreen & Fikru, 2022).

Insecure land tenure also restricts adoption. Farmers are unlikely to commit to labour-intensive and soil-enhancing practices such as SRI if they do not have long-term rights or security over the land they cultivate. Additionally, the high cost and inconsistent availability of essential inputs such as organic fertilisers and eco-friendly pesticides further constrain adoption. As Gautam, Kumar & Singh (2023) note, input costs remain a critical factor influencing the willingness and ability of farmers to adopt new technologies.

Other notable challenges include poor soil fertility, which undermines confidence in SRI's effectiveness, and the prevalence of pests and diseases, particularly when chemical pesticide use is reduced under SRI systems (Srinivasan *et al.,* 2023). Furthermore, environmental hazards such as floods and droughts, inadequate access to modern farm implements, poor storage systems, and practical difficulties with spacing practices collectively create an environment in which adopting SRI can be perceived as risky or impractical. According to Kato, Matusi & Tanaka (2023), extreme weather events and infrastructural deficits pose serious risks to the implementation of controlled irrigation and other sensitive practices central to SRI.

TABLE 6
THE CONSTRAINTS TO THE ADOPTION OF SYSTEM OF RICE INTENSIFICATION BY FARMERS

Constraints	Frequency*	Percentage (%)
High cost of labour	289	25.04
Cost of transportation	206	17.85
Inadequate resources to finance your farm activities	113	9.79
Poor soil fertility	98	8.49
Land tenure system	83	7.19
Drought	57	4.94
Planting spacing of 25cm – 25cm is difficult	50	4.33
High cost of inputs e.g Herbicides, organic fertiliser and pesticides	49	4.25
Poor storage system	46	3.99
Flood incident	45	3.90
Low extension contact/services	44	3.81
Inadequate access to modern farm implements and machinery	37	3.21
Prevalence of pest and diseases	37	3.21

*Multiple-choice Response Recorded
Source: Field survey, 2024.

3.6 Test of Hypotheses:

3.6.1 Null Hypothesis One:

The z-values from the logit regression model were employed to test the first null hypothesis, which states that there is no significant relationship between the socioeconomic characteristics of rice farmers and their adoption of the System of Rice Intensification (SRI). As presented in Table 7, the log-likelihood value of –162.3034 and the Wald chi-square statistic of 53.20, significant at the 1% level, confirm the overall statistical significance of the model. These results indicate that the explanatory variables included in the regression model collectively influence the adoption of SRI among rice farmers in the study area.

Among the variables tested, six were found to be statistically significant: age, sex, level of education, household size, rice farm size, and annual income. This outcome clearly demonstrates that the adoption of SRI is shaped by farmers' demographic and socioeconomic profiles. Consequently, the null hypothesis is rejected, and the alternative hypothesis is accepted—there is a statistically significant relationship between the socioeconomic characteristics of rice farmers and their adoption of the System of Rice Intensification.

3.6.2 Null Hypothesis Two:

To test the second null hypothesis, which posits that there is no significant relationship between the use of SRI-recommended practices and the factors influencing adoption, the Pearson correlation analysis was applied. The results are presented in Table 5.

The analysis revealed statistically significant positive correlations between several variables. Specifically, there was a correlation coefficient of 0.5315 between nursery planting and household size, 0.3129 between nursery planting and rice farm size, 0.0375 between spacing and rice farm size, and 0.4904 between age and the use of organic fertilizer. These significant relationships suggest that as the values of these influencing factors change, so too does the likelihood of adopting specific SRI practices. Given the statistical significance of these correlations, the second null hypothesis is also rejected. Therefore, it is concluded that there is a significant relationship between the use of SRI-recommended practices and the factors influencing their adoption.

TABLE 7
THE RESULT OF THE PEARSON CORRELATION TEST

Pearson Correlation		Nursery planting	Spacing 25cm-30cm apart	Use of organic fertiliser
Age	Sig. (2-tailed) N	1.0000 300	2.1810 300	0.4904** 300
Household size	Sig. (2-tailed) N	0.5315*** 300	1.0000 300	1.000 300
Rice farm size	Sig. (2-tailed) N	0.3129* 300	0.0375** 300	1.0000 300

*** = significance at 1%, ** = significance @ 5% and * = significance @ 10%.

Source: Field survey, 2024

IV. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion:

The study revealed that variables such as age, gender, education level, household size, rice farm size, and annual income significantly influenced the adoption of the System of Rice Intensification (SRI) among rice farmers in the study area. Hence, the null hypothesis stating no significant relationship between socioeconomic characteristics and SRI adoption is rejected. Similarly, the second null hypothesis is rejected due to the significant results from the Pearson correlation analysis, confirming a relationship between the implementation of SRI practices and factors influencing adoption. These findings highlight the need for context-specific strategies, including targeted extension services and capacity-building programs, to enhance the effective and widespread adoption of SRI for sustainable rice production in the study area.

4.2 Recommendations:

Based on the findings of this study, the following recommendations are proposed to improve the adoption and effective implementation of System of Rice Intensification (SRI) practices:

a) Government and agricultural development agencies should promote the use of labour-saving technologies such as mechanised weeders and rice transplanters to reduce the high labour demand associated with SRI. Community-based labour-sharing cooperatives can also be encouraged through support from local governments.

b) Non-governmental organisations (NGOs), women-focused groups, and agricultural extension services should design and implement gender-sensitive programs that empower female farmers with training, access to finance, and tailored support to increase their adoption of SRI practices.

c) Microfinance institutions, commercial banks, and government credit schemes should provide low-interest loans or input subsidies to smallholder rice farmers to help them adopt and sustain SRI practices.

d) Ministries of agriculture and ICT innovators should collaborate to utilise social media, mobile applications, and other digital platforms for timely dissemination of SRI information, advisory services and market updates.

e) Youth development programs and agricultural entrepreneurship schemes should actively engage and support young farmers in adopting SRI, including offering start-up kits, technical mentoring, and agribusiness incubation.

f) Federal and state governments should subsidise key agricultural inputs such as organic fertilisers and provide access to affordable, modern farm implements through public-private partnerships.

g) Extension service providers and ADPs should be strengthened with adequate funding, staffing, and training to ensure regular contact with farmers and effective delivery of SRI-related technical support.

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