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FOREWORD

I am pleased to put into the hands of readers Volume-8; Issue-1: January-February 2023 of **"International Journal of Environment, Agriculture and Biotechnology (IJEAB) (ISSN: 2456-1878)",** an international journal which publishes peer reviewed quality research papers on a wide variety of topics related to **Environment, Agriculture and Biotechnology**. Looking to the keen interest shown by the authors and readers, the editorial board has decided to release issue with DOI (Digital Object Identifier) from CrossRef also, now using DOI paper of the author is available to the many libraries. This will motivate authors for quick publication of their research papers. Even with these changes our objective remains the same, that is, to encourage young researchers and academicians to think innovatively and share their research findings with others for the betterment of mankind.

I thank all the authors of the research papers for contributing their scholarly articles. Despite many challenges, the entire editorial board has worked tirelessly and helped me to bring out this issue of the journal well in time. They all deserve my heartfelt thanks.

Finally, I hope the readers will make good use of this valuable research material and continue to contribute their research finding for publication in this journal. Constructive comments and suggestions from our readers are welcome for further improvement of the quality and usefulness of the journal.

With warm regards.

Editor-in-Chief
Date: March, 2023

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Supply of urban centers with energy resources and the need to preserve the environment case of coal consumption at Baco-Djicoroni

Approvisionnement des centres urbains en ressources énergétiques et nécessité de la préservation de l'environnement cas de la consommation de charbon à Baco-Djicoroni

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Abstract— *In Mali, with strong population growth, forest resources are under multiple pressures, the most important of which are agricultural clearing, land speculation and the consumption of wood and/or charcoal as energy fuel. Studies have shown that this is a major problem. According to the FAO (2020, p 21), its production from 2010 to 2018 increased from 137,907 to 379,124 tons against 79,221 Qm to 334,454 Qm between 2008-2017 (MEADD, 2018, pp 41 and 73). The objective aims to demonstrate the challenges of charcoal consumption as fuel in the Baco-Djicoroni district of the Bamako district in order to raise the awareness of decision-makers. The sampling involved 190 people (160 randomly selected households, 24 traders/wholesalers and 6 technical service agents). The methodology was based on the exploitation of documents, the field survey and the analysis and processing of data using Word, Excel and SPSS software. The analysis of the results records 12 charcoal sales depot sites in Baco-Djicoroni with a sales capacity of 7750 bags per week whose households of 10 to 14 people are the biggest consumers, us 89 bags per month. In a context of climate change and forest preservation, the development of a strategy is necessary and alternatives to charcoal remains the promotion of renewable and/or alternative energies.*

Keywords— ***Issue, charcoal, population, environment, Baco-Djicoroni.***

I. INTRODUCTION

Face à la croissance démographique, à l'exploitation industrielle et aux facteurs climatiques, les forêts du monde ont diminué de 5,16 millions à 9,8 millions d'hectares entre 2010-2020 par an dont 3,94 millions pour l'Afrique et 2,60 millions pour l'Amérique du Sud (FAO, 2020, p. 11). A ce rythme, les forêts disparaitront de la surface du globe dans 775 ans. Le Mali ne fait pas exception et la diminution de ses forêts est beaucoup plus liée à la consommation de bois. Selon le rapport du MEADD (2018, pp. 41, 72 et 73), elle est estimée à 459 kg par personne et par an. Quant à l'exploitation du charbon

de bois, elle est passée de 79221 quintal métrique (Qm)[1] en 2008 à 334 454 Qm en 2017, soit un taux d'augmentation de 322%. En guise de prevue, l'approvisionnement de Bamako en bois énergie pour l'année 2016 a nécessité 1 095 070,33 stères[2], soit une coupe à blanc (50 stères/ha) de 21901,40 ha d'une formation végétale de type savane arborée. Selon les résultats du CIRAD et *al*, (2017, p. ix), la consommation annuelle 2015 des ménages urbains et ruraux du bassin d'approvisionnement de Bamako était de 177 910 tonnes pour le charbon de bois. En 2017, 109 000 tonnes de charbon de bois sont produites et transportées vers la ville de Bamako. De ces quantités, 12 communes, hors rayon des 150 km de la zone d'étude, exportent 33 326 tonnes soit 25% de la demande de Bamako CIRAD et *al*, 2017, p. 90). La même source mentionne sur la page x, que le charbon de bois représente 32% de la demande rurale et 86% de la demande urbaine (en tonnes équivalent bois).

Baco-Djicoroni, un quartier de Bamako en pleine expansion, ne fait pas exception à cette règle. C'est ainsi, que cette étude s'est fixée comme objectif d'analyser les enjeux de l'approvisionnement de Baco-Djicoroni en charbon de bois afin de mieux gérer les ressources forestières du Mali.

II. CADRE GEOGRAPHIQUE DE L'ETUDE

L'étude a été réalisée à Bacodjicoroni. Baco-Djicoroni est l'un des quartiers de la Commune V du district de Bamako (figure 1). La commune a été créée par l'ordonnance n°78-34/CMLN du 18 août 1978. Couvrant une superficie de 41 km^2, elle comprend 8 quartiers administratifs qui ont été presque tous progressivement régularisés et viabilisés. En effet, à l'exception du quartier de SEMA 1, tous ont été d'abord des villages ou des quartiers spontanés avant d'être phagocytés puis réhabilités dans le cadre de leur intégration progressive dans le tissu urbain entre 1983 et 1992. Il existe un centre principal d'état civil et 5 centres secondaires d'état civil.

Baco-Djicoroni, qui fait l'objet de la présente étude est limité à l'est par Torokorobougou et Sabalibougou, au nord-ouest par le cours du lit du fleuve Niger et au sud-ouest par la commune de Kalaban-coro.

Selon le recensement général de la population et de l'habitat de 2009, Baco-Djicoroni comptait 10 930 ménages répartis dans 6 902 concessions, avec 31 382 hommes contre 30 625 femmes pour un total de 62 008 habitants. Etant donné que Baco-Djicoroni est un quartier en pleine expansion, les chiffres ne cessent de progresser. Ainsi, sa population, selon une prévision de la DRSIAP (2017) du district de Bamako, est passée de 119 608 habitants (59 793 hommes contre 59 815 femmes) en 2014 à 138 222 habitants (69 098 hommes contre 69 124 femmes) en 2016 pour atteindre 148 589 (74 280 hommes contre 74 309 femmes) en 2017.

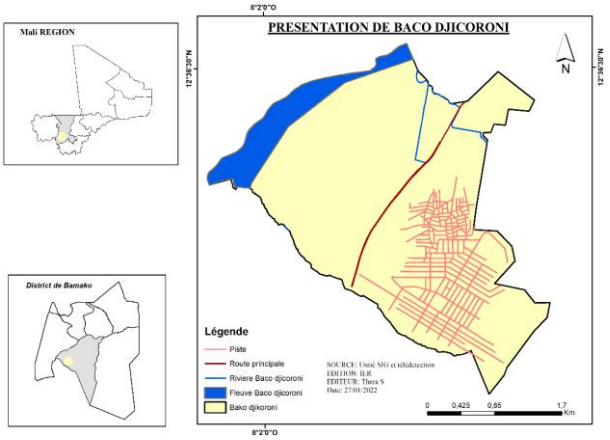

Fig. 1 : Carte de la zone d'étude.

A travers le PDESC, le bien-être des populations dans un environnement saint est au cœur des activités à Baco-Djicoroni. Notamment avec le programme Objectif Secteur Assainissement dont le slogan est : Cité verte débarrassée de toutes pollutions et nuisances par l'aménagement des 100 rues les plus dégradées de la Commune V. Pour Baco-Djicoroni il s'agit d'assurer l'information, la sensibilisation et l'organisation des bénéficiaires d'ouvrages d'assainissement, de réaliser le pavage des caniveaux et l'éclairage publique des 100 rues, d'aménager 5000 ouvrages d'assainissement autonomes avec puisards et accessoires, d'installer des ouvrages d'assainissement collectifs et semi collectif (mini égouts), d'acquérir et d'aménager un terrain pour la création de dépôts de transferts et d'une décharge finale pour la rive droite, d'organiser les GIE en coopérative et les doter d'équipements, … Il est important de noter que la question environnementale de Baco-Djicoroni ne se limite pas seulement à la question de l'assainissement. La Santé, Eau Potable, l'énergie, Urbanisme et Habitat, Sports et Jeunesse, Sécurité et Protection Sociale, Développement Social, Promotion de la Femme et Société Civile, l'éducation concours à la création d'un environnement dont il fait agréable à vivre.

III. MATÉRIELS ET METHODES

3.1. Matériels

Pour la collecte des informations sur le terrain, les outils de collectes ont été le questionnaire et les guides d'entretien pour la collectes des données, les téléphones Smartphones

[1] Un Qm (quintal métrique) équivaut à 100 kg de charbon

[2] 1 stère équivaut à 230 kg

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pour l'enregistrement des interviews et la communication, les logiciels Word, Excel et SPSS pour la saisie des données et la réalisation des graphiques. L'application « *kobocollet* » pour la géolocalisation des infrastructures de stockages ont été également utilisés.

Le questionnaire a porté sur quantité du charbon de bois, sur les acteurs impliqués dans le processus de ravitaillement, sur les sources d'approvisionnement, sur les types d'équipement et les consequences de l'exploitation du chrabon de bois sur l'environnement. Les guides d'entretiens ont porté sur les textes juridiques et regementaires, sur les sytemes de gestion.

3.2. Méthodes

Pour l'atteinte des objectifs de l'étude, la méthodologie s'est appuyée sur l'exploitation des documents, l'enquête de terrain et l'analyse et le traitement des données.

3.2.1. La recherche documentaire

Elle a porté sur les documents généraux et spécifiques ayant abordé la thématique étudiée. Pour ce faire, on a surtout fait recours aux documents des services administratifs et techniques chargés des questions environnementales. Il s'agit entre autres de la Direction des Eaux et Forêts (DNEF), du Ministère de l'Environnement (ME), de l'Agence de l'Environnement et du Développement Durable (AEDD), de l'Agence Nationale pour le Développement Durable. La consultation des thèses et des mémoires ayant traités le sujet nous a amené au niveau des bibliothèques des Universités publiques et privées au Mali, des Grandes Ecoles et des Instituts de recherche. Les centres de ressources documentaires des Collectivités territoriales ont été également fréquentés. Cette phase a été couronnée par une consultation de plusieurs sites web.

3.2.2. L'enquête de terrain

La collecte de données a été faite en deux phases.

Dans un premier temps, il s'agissait pour nous d'avoir des données qualitatives. Elles ont été obtenues auprès des élus locaux, des responsables des structures techniques en charges des questions environnementales, des leaders communautaires et des coopératives. Les interviews ont été réalisées grâce à deux guides d'entretien. Le Premier guide d'entretien a permis de s'entretenir avec les responsables administratives, politiques et techniques tandis que le deuxième nous a permis d'interviewer les représentants des coopératives et les charbonniers.

Dans un second temps, des données quantitatives ont été collectées à l'aide d'un questionnaire. Une enquête a été réalisée auprès de 190 personnes composées de 160 consommateurs (chefs de ménages ou son remplaçants), de 24 vendeurs de charbon (12 grossistes collecteurs et 12 tacherons), de 4 agents de services techniques et administratifs en charge de la gestion forestière et de 2 representants de regroupement associatif (1 responsable de la cooperative et 1 leader communautaire).

Nous avons fait le choix d'un échantillonnage raisonné et aléatoire systémique. Sur la base de la croissance démographique la plus importante du district de Bamako, le quartier de Baco-Djicoroni a été retenu. Sur cinq secteurs que composent le quartier Baco-Djicoroni, deux secteurs ont été retenus soit les secteurs de Baco-Djicoroni Golf et Dougoukoro. Par leurs caractéristiques démographiques et morphologiques, ces secteurs reflètent valablement les trois autres. 160 chefs de ménages et/ou son representant de ces deux secteurs ont été soumis à un questionnaire préétabli comprenant une trentaine de variables. Le questionnaire a été adressé aux 80 ménages, à 80 achêteurs de charbon dans le grand marché de Baco-Djikoroni et aux 24 vendeurs de charbon.

Les 80 chefs de ménages ou son remplacant ont été choisis selon leur disponibilité dans la famille lors de nos passages. De cet effectif, 35 ont les âges compris entre 25 et 45 ans, 25 sont âgées de 45-60 ans et les 20 ont aux moins 25 ans.

Les 80 achêteurs âgées d'au moins de 18 ans et plus ont été selectionnées au hazard lors de leur passage pour achêter du charbon auprès des vendeurs detaillants du charbon de bois dans le grand marché de Baco-Djikoroni. Selon leur disponibilité, ils ont été soumis à notre questionnaire.

Quant aux agents de service techniques et administratifs en charge de la gestion forestière et les representants de regroupements associatifs, ils ont été choisis selon les conseils du premier responsible du service technique.

En plus de cela un inventaire systématique a permis d'identifier 12 dépôts (figure 2) de vente de charbon de Baco-Djicoroni.

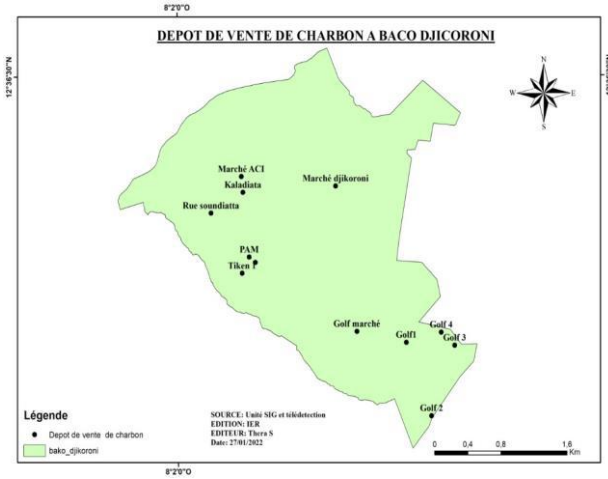

Fig. 2 : Carte des depots de vente de charbon

Quant à l'enquête auprès des ménages, elle s'est déroulée du 16 au 31 janvier 2022. Elle a concerné deux cibles, à savoir les ménages et les revendeurs détaillants du charbon de bois. Les chefs de ménages, dans la plupart des cas se sont faits représentés par leurs épouses qui semblent être mieux placées pour répondre aux questions.

3.2.3. L'analyse et traitement des données

Après la collecte des données de terrain, on a procédé à un dépouillement des fiches d'enquête, leur saisie et leur analyse à l'aide du logiciel SPSS. Le logiciel Excel a permis de réaliser les tableaux et les figures.

IV. RESULTATS ET DISCUSSIONS

4.1. Caractéristiques sociodémographique des enquêtés

L'analyse des résultats de l'enquête auprès des ménages montre que 75% des enquêtés sont des femmes, âgés de plus de 40 ans (66,25%) et vivent en union (86,25%) contre 10% de veuf (e) et 3,75% de divorcés, avec des niveaux de formation secondaire (48,75%), alphabétisé (2,5%), coranique (8,75%) et analphabète (13,75%).

En ce qui concerne les grossistes collecteurs, sur les 12 dépôts de vente inventoriés, 67% sont des hommes, vivant en union (84%) contre 8% de veufs et de divorcés (8%). Les résultats révèlent que 58% n'ont reçu aucune formation. Cependant, 25% se sont limités au niveau primaire contre la formation medersa et alphabétisation à proportion égale soit 8% de l'échantillon. La moitié des vendeurs sont membres d'une association soit 50% des enquêtés.

En ce qui concerne la situation sur le nombre de personnes par ménages enquêtés, le tableau 1 nous donne des renseignements sur leur effectif.

Tableau 1 : nombre de personne par ménage

Nombre des personnes par ménage	Effectif	%
Moins de 10 personnes	76	47,50
10 à 14 personnes	62	38,75
Plus de 14 personnes	22	13,75
Total	160	100

L'analyse du tableau 1 montre que la majorité des ménages enquêtés est composée de moins de 10 personnes soit 47,50% de l'échantillon. Seulement 11% des ménages ont plus de 15 personnes. Cette taille de ménage issue de nos résultats corrobore avec celle de l'INSAT (2015, p. 37) où elle s'établit à 7,1 personnes par ménage et varie considérablement selon le milieu de résidence, passant de 5,7 personnes par ménage en milieu rural à 8,5 en milieu urbain. Selon la même source, cette taille c'est a dire le nombre de personnes vivant quotidiennement ensemble dans le ménage est un élément qui contribue à augmenter les besoins de consommation du ménage en charbon de bois (INSAT, 2015, p. 35).

4.2. Etat de lieux des principes de fonctionnement de la production et de l'approvisionnement en charbon de bois au Mali

Les informations ont été recueillies auprès des charbonniers commerçants de Baco-Djicoroni et de l'association de l'Union (un regroupement de 10 associations créer depuis 2018) Nationale des Sociétés Coopératives des Exploitants Producteurs forestiers du Mali.

La production de charbon de bois ce fait en rapport avec la loi 10-028 du 8 juillet 2010[3] qui détermine les principes de gestion des ressources du domaine forestier national. Elle stipule en ses articles 32 et 33, qu'on ne doit jamais exploiter du bois en République du Mali sans un plan d'aménagement établit sur une période de 10 ans. Le plan est fait par la DNEF à la demande d'un particulier, d'une association ou même d'une collectivité. Selon le président de l'association, la production du charbon de bois ce fait dans le respect de l'environnement, et destiné à la consommation nationale. Même si le plan d'aménagement se fait sur plusieurs années, l'évaluation se fait chaque année. Sur les 12 mois de l'année, les 6 premiers mois concernent l'exploitation et les 6 autres prennent en compte les mesures compensatoires (reboisement, restauration de sol….). Le plan identifie dans un premier temps, les arbres à ne pas abattre comme le néré, le baobab, le karité le *zaban* (arbres fruitiers) ; ensuite les arbres à abattre avec le document qu'on appelle le permis de coupe qui identifie clairement le nombre d'arbre. Les prix en franc CFA (permis cota) diffèrent selon le type d'arbre. Pour couper un *Caïcedrat*, il faut payer 40 000FCfa par l'unité, le *Guenou* ou Pterocarpuserinaceus entre 10 000 à 20 000FCFa, le *Boumou* ou kapokier à fleurs rouges à 8 000FCFa l'unité, le *Sanna* ou *Daniellia Oliveri* entre 10 000 à 11 000FCFa, etc. Pour avoir le droit de produire le charbon à travers un plan d'aménagement, il faut avoir la carte d'exploitant accessible à 60 000FCFa. A Chaque plan est associé une coopérative locale qui joue un rôle de surveillance, car motivé par une partie de l'argent qui lui est reversé. Pour ce qui est de la chaine d'approvisionnement, le charbon est

[3] La loi 10-028 stipule en ses articles 32 et 33, qu'on ne doit jamais exploiter du bois en République du Mali sans un plan d'aménagement établit sur une période de 10 ans.

produit par les paysans sur place auprès de qui les grossistes (dépositaire de Baco-Djicoroni) viennent s'approvisionner. Les points de ventes qui sont un peu partout dans le quartier sont alimentés par les grossistes. En plus des points de vente il y'a également les tricycles et les charrettes aussi qui s'approvisionnent auprès des grossistes pour se déplacé vers les clients.

4.3. Acteurs impliqués dans le processus de ravitaillement du charbon de bois de Baco-Djicoroni

Divers acteurs interviennent dans le processus du charbon de bois consommés à Baco-Djicoroni. De la production à la consommation, ils sont composés de charbonniers bucherons, de charbonnier commerçant ou grossiste collecteur, de tâcheron et des commerçants détaillants. Les charbonniers bucherons ne résidant pas à Bamako, ravitaillent le charbonnier commerçant en collaboration avec le tâcheron qui ravitaille à son tour le commerçant détaillant de Baco-Djicoroni. Les charbonniers bucherons sont généralement des paysans qui la pratiquent en dehors des périodes agricoles. Selon les résultats auprès des charbonniers commerçants, les charbons de bois consommés à Baco-Djicoroni viennent de Bougouni, Kolondièba à proportion égale soit 42% et de Kita soit 16% de l'échantillon. En ce qui concerne le tâcheron, il est employé par le charbonnier commerçant qui le paye quotidiennement ou qu'il l'embauche.

La diversité des acteurs intervenant dans le processus du charbon de bois Bamako est une réalité constatée par d'énormes études. L'étude du MEADD, 2015, p. 176 mentionne entre autres les bûcherons, les charbonniers, les commerçants- transporteurs et les revendeurs. L'analyse de GAZULL L. (2009, p. 101) annonce que l'approvisionnement de Bamako est le fruit d'un grand nombre d'acteurs interdépendants du détaillant pour vendre au grossiste qui l'approvisionne, en passant par le transporteur et le producteur. Pour GAZULL L. (2009, p. xii) l'ensemble de ces acteurs en interactions forme une filière, ce qui fait que l'approvisionnement des villes maliennes est actuellement le fait d'un réseau d'échanges entre de nombreux acteurs intermédiaires aux fonctions, aux comportements et aux localisations diverses.

L'analyse des résultats mentionne que le charbon de bois consommé à Baco-Djicoroni provienne de diverses localités (Kita, Kolondièba et Bougouni) du Mali, à une distance de plus de 150 km de Bamako. Ce qui corrobore avec l'étude de CIRAD/FONABES (2017, p. 90), qui mentionne que 35% du charbon de Bamako proviennent de 12 localités (Bamafele, Kolondièba, Kita, Niena, Djidian, Sebeté, Sanso, Garalo, Defina, Kebila, Kadiolo, Koumantou) de plus 150 km de Bamako. L'étude du MEADD (2015, p. 28) se fit de l'identité des zones d'approvisionnement en se limitant du potentiel forestier dont la capacité est estimée à près de 37,7 millions d'hectares avec un volume sur pied d'environ 3,7 milliards de m^3 et une productivité pondérée sur l'ensemble du pays d'environ 0,86 m^3/ha/an.

4.4. Source d'approvisionnement et quantité de charbon consommée

L'enquête de terrain auprès des charbonniers commerçants nous dévoile des informations sur la capacité de vente de charbon de bois à Baco-Djicoroni (tableau 2).

Tableau 2 : Capacité de ventes des dépôts de Baco-Djicoroni par semaine.

Nom de dépôt	Nombre	Nombre de sacs /Semaine
Marché Djicoroni	1	2000
Golf 2, Golf 3 et Golf 4	3	1000
Kaladiata, Mairie, Tiken 1, Marché ACI	4	500
Rue Soundiata, Tiken 2, PAM	3	250
Total	12	7750

L'analyse de la figure 2 nous renseigne que les 12 sites de dépôt de vente de charbon ont une capacité de vente de 7750 sacs par semaine. Il est à rappeler qu'un sac de charbon a en moyenne 34 kg. Ce qui correspond à 34 kg x 7750 qui est égale à 263 500kg (ou 263,5 tonnes) de charbon de bois consommé par semaine à Baco-Djicoroni.

En termes de consommation des ménages, les données sur la quantité de charbon utilisée par les ménages figurent dans le tableau 3.

Tableau 3 : Quantité mensuelle de charbon utilisée par ménage

Catégories de ménage	Quantité de sac* de charbon utilisée par mois	%
Moins de 10 personnes	59,5	31,23
10 à 14 personnes	89	46,71
Plus de 15 personnes	42	22,06
Total	190,5	100

* Un sac pèse en moyenne 34 kg

L'analyse du tableau 3 montre que les ménages de 10 à 14 personnes sont les plus grands consommateurs de charbon soit 89 sacs par mois. Par contre, les ménages de plus de 15 personnes consomment seulement 42 sacs par mois. Cela montre que la consommation du charbon de bois n'est pas forcement liée au nombre de personne. Elle est le type de combustible de préférence de la plupart des ménages enquêtés soit 91,25% de l'échantillon contre 8,95% de bois. Nos résultats ont montré que les ménages de 10 à 14 personnes sont les plus grands consommateurs de charbon soit 89 sacs par mois. L'étude du MEADD (2015, p. 128) mentionne que cette forte quantité utilisée par les ménages peut dépendre du type de bois utilisé pendant la production du charbon même si au Mali on rencontre un mélange d'espèces dans un sac de charbon. Il confirme que certaines espèces végétales ont une forte quantité de calorie. Ce qui fait que le sac de charbon avec une forte quantité des espèces végétales comme Tabacoumba (Detarium microcarpum) soit 24 967 KJ/kg, N'Waniaka (Combretum Velibinum) soit 24 523 KJ/Kg, Wolotié (Terminalia laxiflora) soit 24312KJ/Kg, N'Kolobe (Combretum micrathum) soit 23 850KJ/Kg, Sinjan (Cassia sieberiana) soit 21 495… peut être utilisé pendant un temps plus ou moins long par rapport aux autres espèces végétales (MEADD, 2015, p. 176). Ce constat est confirmé par l'étude de FONABES (2017, p. 86) qui mentionne qu'en 2015, la ville de Bamako a consommé 288 tonnes de charbon par jour pour une population de 2 396 800 habitants. Il signale à la page 103, qu'un détaillant peut vendre au moins 7 sacs de charbon par semaine dont le poids pour un sac de dimension standard est estimé à 39,28 kg. Cette forte consommation passant de 137 907 en 2010 à 379 124 tonnes en 2018 est confirmée par l'étude de l'Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO) (FAO, 2020, p. 21). Nos résultats montrent que les vendeurs de charbon de Baco-Djicoroni sont des permanents. Ce qui est confirmé par à l'étude de GAZULL L. (2009, p. 158) ou ils deviennent en plus d'être permanent, des intermittents et des occasionnels. Le chiffre d'affaire de ses revendeurs est compris entre 6000000 et 15000000 FCFA selon la quantité de charbons écoulée en une semaine (FONABES, 2017, p. 81).

4.5. Types d'équipements

L'analyse des résultats révèle que 81% des ménages utilisent le fourneau traditionnel contre 10% pour le fourneau amélioré et 9% pour le fourneau moderne (Photos 1). Ces types de fourneaux déterminent la quantité de charbon consommé par les ménages.

a) fourneau traditionnel *b*) fourneau amélioré

c) fourneau moderne

Photo 1: Types de fourneaux à charbon [a) fourneau traditionnel, b) fourneau amélioré, c) fourneau moderne).

Source: Fichiers personnels, janvier 2022

L'analyse des images ci-dessus montre les types de fourneau répertorié dans les familles lors de notre enquête. Chaque type de fourneaux utilisé par les ménages enquêtés détermine leur niveau de vies. Il est aussi un facteur déterminant en matière de consommation de charbon. Au dire des enquêtés, les fourneaux modernes sont beaucoup plus économiques que ceux traditionnels. Dénommé fourneaux Wassa, Daamu, Sewa, Nafacaman par l'étude du MEADD (2015, p. 33), les types de fourneaux répertoriés lors de nos enquêtes déterminent la quantité de charbon consommé par les ménages. Les fourneaux traditionnels sont les plus utilisés par nos enquêtés. Cela est probablement dû à la disponibilité et à l'accès facile par la population à ce type de fourneau. Les résultats de l'étude menée par FONABES (2017, p. 22) ne partagent pas ce constat. Dans la zone d'étude de FONABES les foyers les plus vendus sont les foyers dits améliorés ou performants même si la vente des foyers à charbon de bois représente 54% de la vente totale de foyers. Il mentionne à la page 133, qu'en moyenne 55 foyers à charbon de bois sont vendus par point de vente par mois pour un chiffre d'affaire moyen de 205 500 FCFA par vendeurs. Les foyers améliorés SEWA (métallique avec insert en céramique) représente 40% des ventes. Les fourneaux métalliques et les foyers 4-Carrés ont des parts de marché respectives de 33 et 27%.

4.6. Analyse des conséquences de la consommation du chabon de bois sur l'environnement et la population

L'ensemble des ménages enquêtés reconnait de façon unanime que l'utilisation du charbon de bois comme combustible principal a des conséquences sur l'environnement et sur la santé et la sécurité alimentaire de la population (tableau 4).

Tableau 4 : Perception de la population sur les conséquences du charbon de bois

Conséquences sur l'environnement	%	Conséquences sur la population	%
Déforestation	80,00	Rareté des pluies	5,00
Désertification	20,00	Famine	95,00
Total	100	Total	100

L'analyse des résultats révèle que 80% des personnes enquêtées mentionnent la déforestation et 95% la famine comme les principales conséquences de la consommation du charbon de bois sur l'environnement et sur la population. Les résultats montrent aussi que 95% des ménages enquêtés semblent ignorer que la famine mentionnée comme conséquence n'est que le résultat de la rareté de pluie.

Quant à l'analyse issue des résultats des entretiens avec des agents des services techniques ce sont la dégradation du sol, la réduction des superficies boisées dus à l'émission du gaz à effet de serre, la disparition d'espèces thérapeutiques, l'accentuation des conflits entres les villages pour des superficies boisées, l'exposition de la population aux bandits qui trouvent souvent refuges dans les forêts, etc. ont été mentionnées comme consequences de l'utilisation du charbon de bois. Ce qui corrobore avec les résultats de l'étude de la FAO (2020, p. 6) sur l'évaluation des ressources forestières mondiales, qui estime à 420 millions d'hectares de superficie forestière perdue à cause de la déforestation de 1990 à nos jours. La perte des superficies boisées selon la FAO (2020, p. 1) provoque la dégradation des terres consécutive aux modifications éco-systémiques. Ce qui engendre une perte de la productivité des sols et donc des pertes de revenu agricole considérable. Associée à la mauvaise utilisation des ressources naturelles selon l'analyse de TOURE S. (2020, p. 11), cette perte peut coûter chaque année à l'Etat malien plus de 20% du Produit Intérieur Brut (PIB), soit plus de 680 milliards FCFA. Une autre étude de la FAO (2018, p. 40) mentionne les maladies respiratoires et le temps consacré à la collecte de bois qu'aux moyens d'existence ou à l'éducation des enfants comme impacts sanitaires et socio-économiques majeurs provoqués par la cuisson au bois ou au charbon de bois.

Pour inverser la tendance, les Groupements d'Interet Economiques (GIE) (Yirimex, Green-ENERY, Africa-Energy etc.), font la promotion des fourneaux améliorés ainsi que des briquettes combustibles à base de déchets et de résidus agricoles. Le rapport du MEADD (2018, p. 20) et l'étude du GIZ & SCHUTTELAAR M. (2019, p. 6) partagent cet avis. Tandis que la proposition des ménages, pour une gestion durable (promotion des énergies alternatives comme le gaz et de substitution comme le vent, l'eau et le soleil) est soutenue par le rapport des Nations Unies sur le Climat et l'Energie au Mali (UN, 2017, p. 3). Ce rapport met l'accent sur un cadre stratégique de mise en œuvre des efforts pour soutenir des actions ciblées sur le reboisement communautaire. Ce qui corrobore avec l'étude de CIRAD/FONABES (2017, p. 14) qui dans sa planification, met l'accent sur l'exploitation de bois-énergie à travers le développement des énergies alternatives et de substitution. Par contre la Direction de la Gestion Décentralisée des Forêts du Mali (GEDEFOR), met plutôt l'accent sur l'anacarde dans le cadre de la promotion des chaines de valeur, en mettant à la disposition des paysans des graines et des pieds d'anacarde afin de lutter contre la déforestation et la dégradation des sols. Ce qui va dans le sens de la Revue Espace Géographique Et Société Marocaine, 2020, p. 18.

Pour réduire ces conséquences, le reboisement soit 63,75% de l'échantillon prime comme principale solution suivi d'autres alternatives (36,25%) comme le gaz et les énergies renouvelables. Toutefois 36,25% des enquêtés souhaitent remplacer le charbon par le gaz voire les énergies solaire et éolienne, connues par 96,25% des enquêtés. A ceux-ci s'ajoute la promotion des fourneaux améliorés ainsi que des briquettes combustibles (photo 2) à base de déchet et de résidu agricole par les promoteurs privés, ignorées par 90% des personnes enquêtées. Et pourtant à la question, en cas de rupture de charbon de bois, 55% proposent le bois, 26% le gaz et 19% qui pensent qu'ils n'y aura jamais de rupture d'accès au charbon.

Photo 2 : Echantillon de briquettes combustibles

Source : Fichiers personnels, janvier 2022

L'analyse de la photo confirme l'existance d'une autre alternative qui n'est autre que la briquête à base de déchet et de résidu agricole. Cette alternative est très peu connue par le public malien faute d'accompagnement du pouvoir public au dire du responsable en charge de marketing du projet.

En tous les cas, la mise en place des textes réglementaires et juridiques en matière d'exploitation des forêts ne font pas défaut. Ils sont en nombre suffisant et appréciés par les services techniques. En revanche, les textes réglementaires sur la consommation d'énergie dans les ménages sont quasiment absents. L'étude du MEADD (2015, p. 133) avait fait ces constats et confirme que l'application de la transition énergétique au Mali est confrontée à d'énormes obstacles parmi lesquels figurent le manque de politiques solides et durables en matière d'énergie domestique, le manque des structures de contrôles sur la consommation d'énergie domestique, le manque des textes réglementaires sur la consommation d'énergie dans les ménages... Il faut aussi ajouté que l'application des textes posent problème et ont besoin d'être ajustés et/ou complétés. Ce constat est mis en avant par le document de GRIFFITHS T. du Forest Peoples Programme (FPP), (2018, p. 20).

V. CONCLUSION

L'étude a seulement concerné les commerçants/grossistes du charbon de bois, les personnes qui viennent s'approvisionner auprès de ces vendeurs, les agents des services techniques en charge des questions forestières et les promoteurs privés.

L'analyse des résultats révèle que le charbon de bois est la principale source d'énergie de caisson des ménages de Baco-Djicoroni. Cela constitue un enjeu majeur pour l'environnement voire les ressources forestières, surtout dans un contexte de Changement Climatique. Une situation aggravée par une démographie galopante, l'absence d'autres alternatives, la faible exploitation des énergies alternatives, mais aussi du fait qu'elle constitue une source de revenus facile pour les populations. La déforestation, l'avancé du desert, le déplacement des isohyètes, la disparition des espèces végétales constituent des menaces flagrantes que l'homme a causé à son environnement. En outre à l'issue des enquêtes, trouver des alternatives aux charbons de bois et valoriser les initiatives privées (Ségou tillé, Green Énergie, Yirimex…) de production de combustible, comme les briquètes combustibles fait à base de résidus et de déchet agricole… ont été souhaités par les personnes enquêtées.

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Distribution Patterns of Freshwater Prawn, *Macrobrachium* spp. Following Stock Enhancement Programme in Sabah, Malaysia

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Abstract**—** *The decline of the freshwater prawn, Macrobrachium spp. in rivers can be attributed to overfishing, habitat loss and pollution. In order to offset the pressure, a community-based stock enhancement project was initiated by Borneo Marine Research Institute (BMRI), University Malaysia Sabah, to increase the number of Macrobrachium spp. in Petagas River, Putatan, Sabah. This study was conducted to determine the distribution and abundance of different life stages of the freshwater prawn, Macrobrachium spp. following stocking programme. The different life stages of the freshwater prawns were caught using hand net and modified prawn trap. A total of 539 specimens were caught and separated into postlarvae (PL), juvenile and adult. Abundance of PL (53.47%) was found at the downstream region of Petagas River, juvenile (18.06%) was found at the midstream region while adult prawn (81.63%) was found at the upstream region. The distribution of PL prawn was found to be increased with increasing salinities (R^2=0.95) while for juvenile (R^2= 0.98) and adult prawns (R^2=0.921) were inversely correlated. The CPUE of PL, juvenile and adult were positively correlated with the increase of stocking juvenile following stocking programme with R^2=0.89, R^2=0.73 and R^2=0.87 accordingly. The stock enhancement programme is suggested to be implemented continuously to improve the population of Macrobrachium spp. in the Petagas River. This study will provide baseline information on the effectiveness of stock enhancement programme of freshwater prawn especially in Malaysia.*

Keywords— ***stocking, life stages, Macrobrachium rosenbergii.***

I. INTRODUCTION

In Asian countries, stock enhancement is rarely successful, except in the case of enhancement with species capable establishing their breeding populations (De Silva *et al.*, 2005). In Thailand, approximately 70 million of postlarvae of *M. rosenbergii* were stocked into some of the rivers and reservoirs in the stock enhancement programme. Regrettably, there are few quantitative and qualitative data or statistics available on the impacts of these stock enhancement attempts and its cost-effectiveness and impacts on rural communities have been rarely evaluated (Choonhapran *et al.* 2003). While in Malaysia, stock enhancement of *M. rosenbergii* and other freshwater fish are mostly in rivers (Utusan, 2012b; Borneo Post, 2013; Kosmo, 2015; Sinar Harian, 2015). The main objectives of this practice in Malaysia are to increase the population of the stocking species, conservation and preservation of fisheries resources and to assist in the improvement of socio-economic status of fishermen that live along the riverine areas (Borneo Post, 2014). The source of stock for the enhancement may be derived from capture, but more typically is obtained from a hatchery operation. These

features can be referred to culture-based fishery (FAO, 2005).

The *Macrobrachium* spp. can be found in tropical and subtropical regions throughout the world. They are mostly found in inland freshwater areas including rivers lakes, swamps, ponds, canals and as well as in estuarine regions. *Macrobrachium* spp. have been said to be transferred from their origin to the other part of the world for research (FAO, 2002; Wowor and Ng, 2007). In the natural environment, migration of the gravid females from freshwater to estuaries occurs and the eggs hatch out in a higher salinity environment. The larvae are free swimming and consume zooplankton and larval forms of crustaceans. Then, the larvae undergo metamorphosis into postlarvae (PL) and tend to be a benthic organism. At this stage, they migrate upstream towards freshwater to less saline water and grow into adults. They can swim and walk on the sub-stratum and over the damp areas such as rocks, verticals surfaces and sometimes on damp land (FAO, 2002). The salinity ranges preferred for PL was found between 14 to 30 ppt (Sandifer *et al*., 1975; Willführ-Nast *et al*., 1993). While for juveniles and adult are almost the same between 0 to 20 ppt (Limpadanai and Tansakul, 1980; Cheng *et al*., 2003; Chand *et al*., 2015).

A community-based stock enhancement programme of *Macrobrachium* spp. was initiated by the Borneo Marine Research Institute (BMRI), University Malaysia Sabah from year 2012 in Petagas River, Putatan. The main purpose of this programme was to improve the Petagas River condition and its aquatic resources *via* stock enhancement and awareness programmes. Since there was limited data on assessment of stock enhancement in Malaysia, therefore the present study was conducted to assess the stock enhancement programme of *Macrobrachium* spp. by determining its distribution and abundance along the Petagas River, correlation with water parameters and CPUE following the stocking timeline.

II. MATERIALS AND METHOD

Sampling Site

The study was carried out at Petagas River, Putatan located between latitude 05º54.847' and 05º53.889' North and longitude 116º02.744' and 116º04.644' East along the Petagas River (Figure 1).

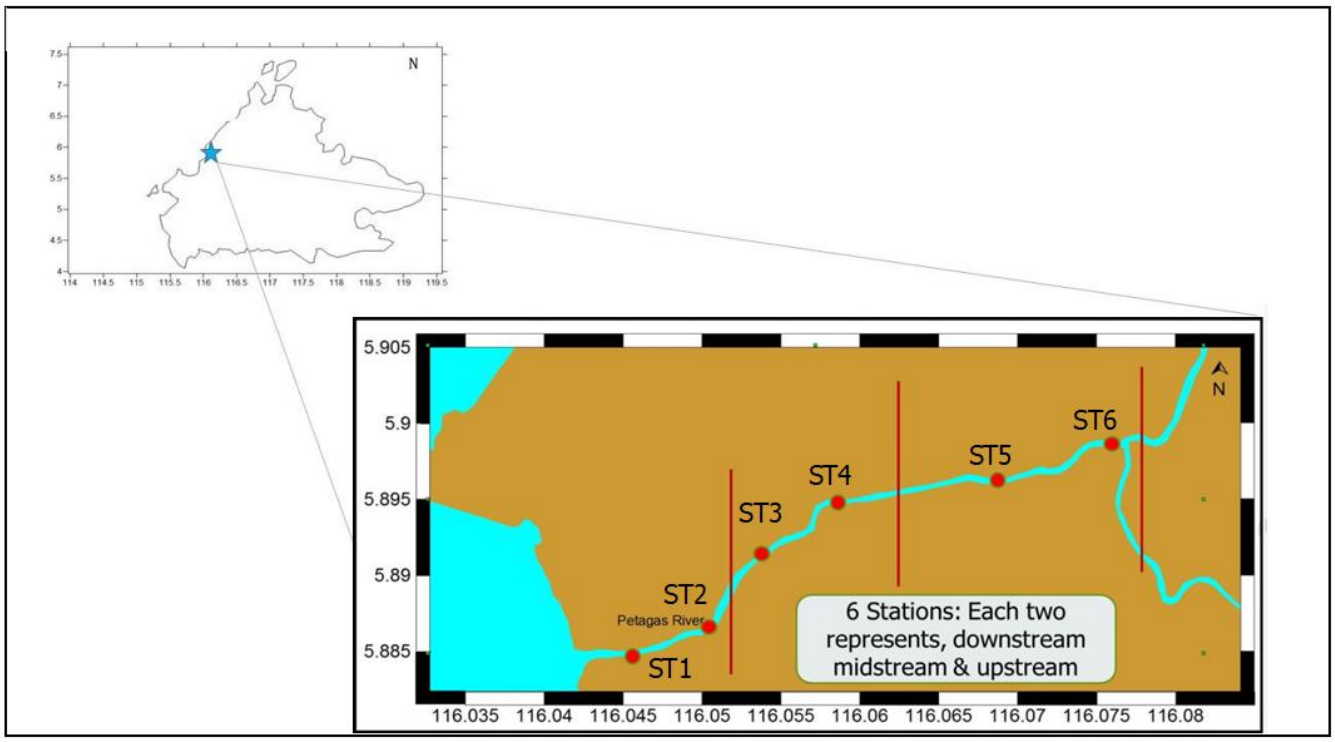


Fig 1. The study site and stations of Petagas River, Sabah at which the samplings were conducted.

Six stations were chosen and selected based on the presence of *Macrobrachium* spp. during the preliminary sampling. The stations were used to determine the distribution and abundance of different life stages of *Macrobrachium* spp. in Petagas River. These stations were divided into three regions i.e upstream, midstream and downstream dependent on their salinity ranges during high tide and low tide.

Sampling Period

Sampling was carried out on three consecutive days after

each stocking phases of *Macrobrachium* spp. juveniles into the Petagas River from September 2013 to May 2015 (Table 1). The assessments of stock enhancement were made after the Phase 3 to 6 releases. No assessment was made on Phase 1 and 2 because the present study was conducted after a year of the BMRI stock enhancement programme started in 2012. Besides, local community also revealed that mass mortality of prawns occurred in few incidents after the releases where local people used '*tuba*' for fishing. '*Tuba*' is derived from leguminous plants, genus *Derris* found in Southeast Asia and the southwest Pacific islands. The roots of *D. elliptica* contain rotenone, a strong insecticide and can poison fish (Fryer and Stenton, 1923). This activity might cause mortality of the *Macrobrachium* spp. juveniles that were released during Phase 1 and 2.

Tab. 1: Assessment of stock enhancement of Macrobrachium spp. juvenile following the stocking programme timeline

Stocking Phases by BMRI	Dates	Number of juveniles	Assessment	Month of sampling
Phase 1	23 Apr 2012	5,000	No assessment	-
Phase 2	06 Dec 2012	6,000	No assessment	-
Phase 3	22 Sept 2013	10,000	Assessment 1	September 2013
Phase 4	18 Jan 2014	3,000	Assessment 2	February 2014
Phase 5	7 Dec 2014	3,300	Assessment 3	December 2014
Phase 6	8 May 2015	10,000	Assessment 4	May 2015
Phase 7	17 Dec 2015	5,000	No assessment	-

Sampling Regime

For the sampling of adult prawn, modified prawn trap (locally known as *bubu)* was used (modified from Bentes *et al*., 2011). Each bubu was 200 cm in length with a diameter of 20 cm and entrance funnel with a mouth diameter of 5 cm. The body and funnel of the trap was covered with 5 mm mesh size. The bubu was made by High-density polyethylene (HDPE)/ plastic green net. The traps with two openings were found to be the most efficient capture device in the Petagas River. Two *bubu* traps were deployed and weighed at each station to prevent the traps from being washed away by the tides or currents. The modified traps were first deployed at high tide and hauled during the high tide the following day which resulted in a total soak time of approximately 24 hours. At the end of the 24 hours, the modified traps were removed, and the prawns caught were placed in a labeled plastic bags and transported to the laboratory in thermal box and crushed ice.

For the sampling of PL and juvenile prawn, littoral dip netting method was adopted by using hand net (Davenport *et al*., 1999; Short, 2004; Arumugam, 2012; Grenfell, 2013; Suguri *et al*., 2015; Tantri *et al*., 2016). A dip net or hand net with a mesh size of 1.5 mm and catch area approximately of 25 x 15 cm^2 was used to collect prawns at each station. The net must reach the bottom of the littoral zone as PL and juveniles of the prawn are now a benthic organism. Dip netting was carried out in water depths between 0.1 to 1.0 m. In order to minimize the bias in collecting data using this method, the dip netting or hand netting was carried out in same amount of catch effort by netting 10 times in each sampling stations, up to a maximum distance of 10 m on either side of the littoral zone. The PL and juvenile of *Macrobrachium* spp. caught were categorized by their total length (PL<14mm>juvenile) follows (Rao, 1991; Kawamura et al., 2015). Abundance of prawn caught was estimated by catch per unit of effort. Total length (TL-measured in mm from the anterior part of the rostrum to the posterior part of the telson) was recorded.

The *In-situ* parameters of the river water (salinity, temperature, pH and dissolved oxygen) were measured at the bottom of water column where the traps were laid at all stations (ST1-ST6) using HANNA Multi-parameter Model HI9828.

Statistical Analyses

Statistical analyses were undertaken using IBM Statistical Package for the Social Sciences (SPSS) Statistics 23 software. Normality tests were carried out using the Shapiro-Wilks ($\alpha < 0.05$) on all the datasets. The data that did not conform to the assumptions of parametric testing were then run using non-parametric tests analyses. Kruskal-Wallis and Mann-Whitney *U* test were carried out in SPSS to assess whether there were statistical differences in the abundances of different life stages of *Macrobrachium* spp. caught at all stations and time. Since the methods of catching (PL-Juveniles) and adult of *Macrobrachium* spp. were different, thus, the set of data on both methods were

separated.

III. RESULT

Distribution and Abundance of Different Life Stages of Macrobrachium spp.

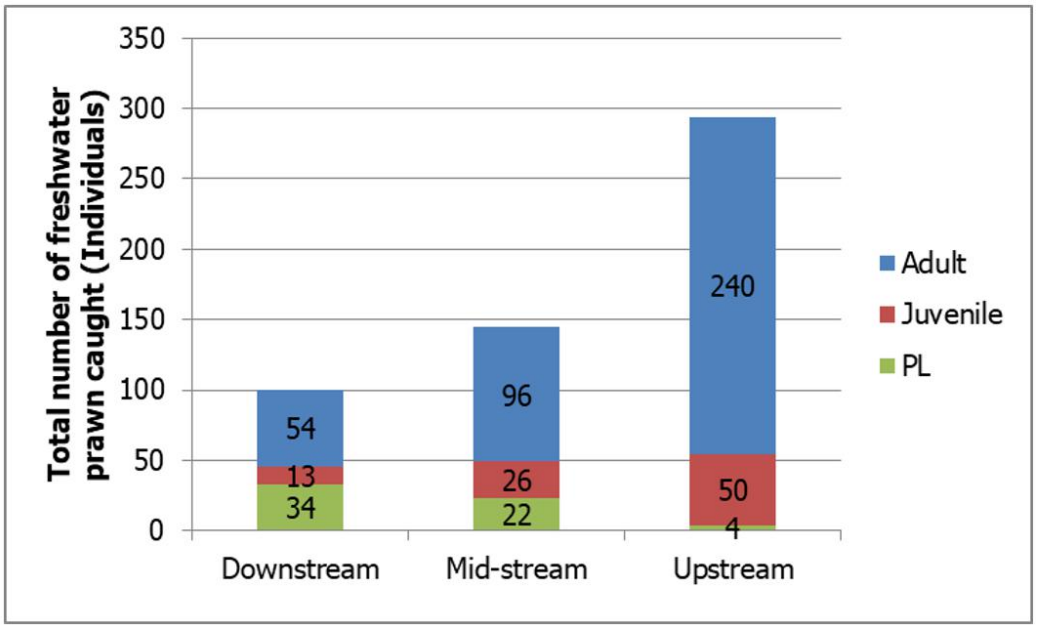
A total of 539 individuals of different life stages of freshwater prawns were caught at different three main regions of Petagas River with 101, 144 and 294 respectively (Figure 2a.). The range of total length of PL was found between 8.4 to 13.9 mm (11.28±1.54 mm) while for juvenile was between 15.8 to 29.2 mm (20.41±3.73 mm). The total length of adult specimens ranged from 56.2 to 120.3 mm (97.2±12.16 mm) (Table 2). At the downstream stations highest percentage (53.47%; n=34) of PL was found (Figure 2a. and 2b.). The lowest abundance of PL was found at the upstream station (1.36%; n=4). The abundance of juvenile freshwater prawn was found to be highest at the midstream stations (18.06%; n=26) followed by upstream (17.01%; n=50) and the lowest by the downstream stations (13%; n=13). Statistical analyses showed a significant different between abundance of juvenile and PL with regions (Kruskal-Wallis; $p<0.05$) except for PL at downstream and midstream regions (Mann-Whitney *U*-test; $p>0.05$). For adult stage, the highest abundance was found at the upstream station (81.63%; n=240) while the lowest at the downstream station (33.66%; n=54) (Figure 2a.) and Figure 2b.). Statistical analyses showed that there were significant differences between the abundance of adult with the river regions (downstream, midstream and upstream) (Kruskal-Wallis; $p<0.05$).

Tab. 2 The total length of sampled prawn in Petagas River

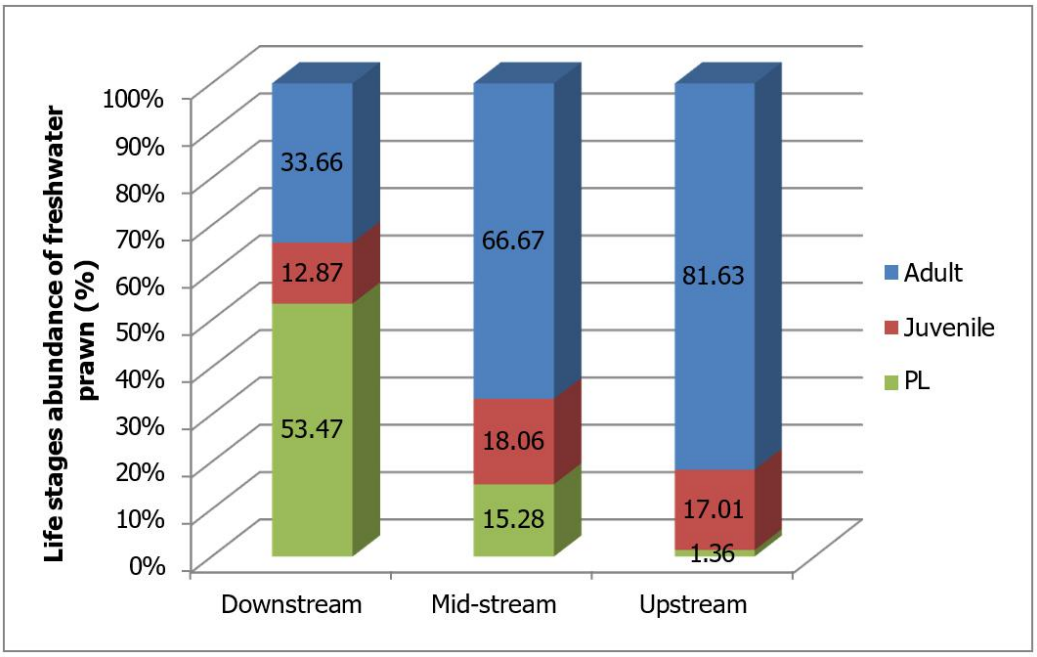
Life stages of prawn	n	Total length (mm)		
		Min	Max	Mean ± Std
Adult	390	56.2	120.3	97.2±12.16
Juvenile	89	15.8	29.2	20.41±3.73[a]
PL	60	8.4	13.9	11.28±1.54[b]

*Abbreviation used on the table: n= total number of specimens, Min= minimum, Max= maximum, Std= standard deviation.

[a,b] showed a significant different ($p<0.05$) of TL between juvenile and PL.



(a)



(b)

Fig 2. (a) The total number of prawns at the three main regions of the Petagas River. (b) The composition of PL, juvenile and adult freshwater prawn caught at three main regions of the Petagas River.

***In-situ* Parameter of Petagas River**

The range of water salinity over the entire study period at Petagas River was between 0 ppt to 32.98 ppt. No significant difference in salinity was found between months ($p>0.05$). Further analyses showed that the salinities in both high and low tides were statistically different between stations (Mann-Whitney *U*-test; $p<0.05$) except for (ST1 and ST2), (ST3 and ST4) and (ST5 and ST6) (Mann-Whitney *U*-test; $p>0.05$) (Figure 3a and 3b).

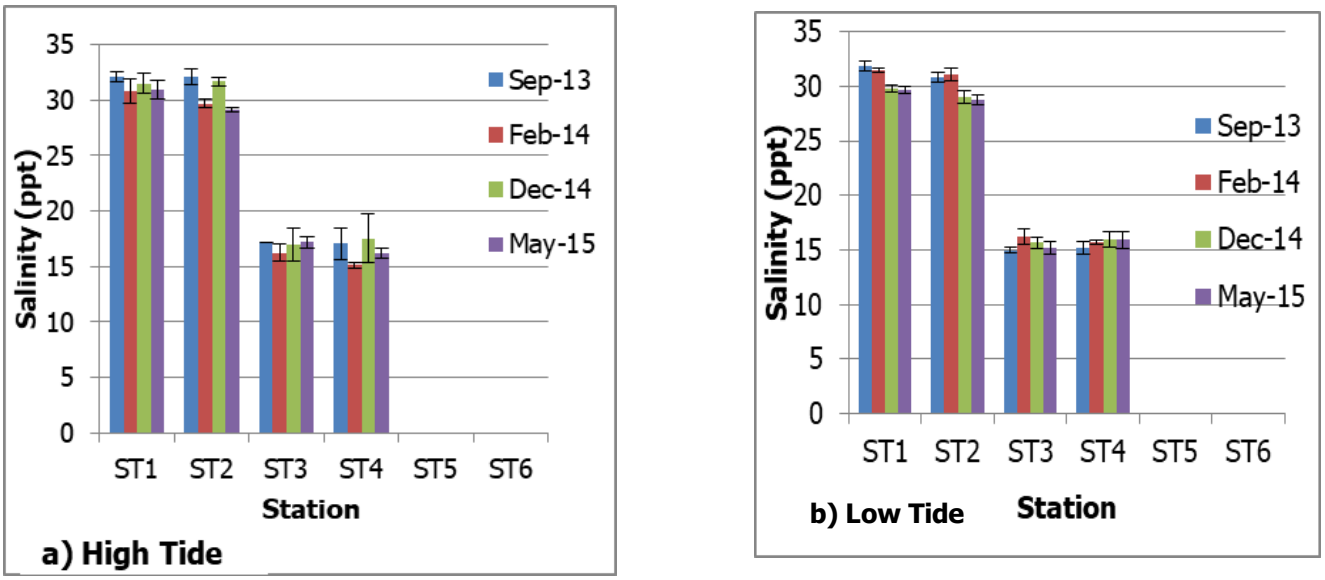


Fig 3.: a) Salinity in ppt at stations along Petagas River during high tide; and b) Salinity in ppt at stations along Petagas River during low tide

The mean of salinities at ST1 to ST6 were 31.32±0.60, 30.65±1.44, 16.89±0.44, 16.49±1.06, 0.00±0.0 and 0.00±0.0 ppt respectively. The stations were categorized into three main regions which were downstream, midstream and upstream according to their range of salinity. The mean of salinities of the regions were 31.28±1.50, 16.79±1.60 and

0.00±0.0 ppt accordingly. Henceforth, throughout this study, the stations were categorized into three regions i.e downstream, midstream and upstream. The mean values of environmental variables are shown in Table 3. The DO varied from 4.56 mg/L (ST1) at downstream station to 7.21 mg/L (ST6) at upstream station. The water pH and temperature of Petagas River were ranging between 6.04 (ST6) to 7.74 (ST1) and 25.83 °C to 28.74 °C respectively between stations.

Tab. 3: Water Parameters at different sampling stations in Petagas River

Para-meter	Salinity (ppt)			Dissolved oxygen (mg/L)			pH			Temperature (°C)		
Station	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**
ST1	31.32 ±0.60	30.78	32.08	4.67 ±0.08	4.56	4.76	7.64 ±0.12	7.49	7.74	27.68 ±1.15*	25.90	28.26
ST2	30.65 ±1.44	29.16	32.09	4.73 ±0.10*	4.66	4.88	6.77 ±0.32	6.44	7.21	27.55 ±0.95	26.15	28.14
ST3	16.89 ±0.44	16.26	17.19	4.78 ±0.06	4.72	4.84	6.61 ±0.24	6.27	6.81	27.55 ±1.09*	25.95	28.34
ST4	16.49 ±1.06	15.13	17.54	5.34 ±0.35	4.86	5.62	6.43 ±0.11	6.30	6.54	27.45 ±1.09	25.84	28.15
ST5	0.00 ±0.0	0.00	0.00	5.52 ±0.46	4.93	6.06	6.22 ±0.08*	6.12	6.31	27.71 ±1.33	25.83	28.74
ST6	0.00 ±0.0	0.00	0.00	5.98 ±0.94	5.16	7.21	6.11 ±0.14	6.04	6.32	27.70 ±1.17*	25.96	28.40

* indicates significant difference between stations ($p<0.05$)

Relationship between Distribution of Macrobrachium spp. and In-Situ Parameters

The distribution of PL increased with increasing salinities and pH. There was a strong correlation between the distribution of PL with salinity (R^2=0.95) and PL with pH (R^2=0.51) (Figure 4 and Figure 5) However, there were opposite trends observed between the distribution of juvenile and adult against both salinities and pH. Their distribution decreased with increasing salinities. The trend showed an inversely strong and positive correlation between the distribution of juvenile (R^2=0.98) and adult (R^2=0.921) with salinity (Figure 4). The same trend can be observed between the distribution of juvenile (R^2=0.62) and adult (R^2=0.61) with pH (Figure 5).

The distribution of juvenile and adult freshwater prawns increased with increasing dissolved oxygen (DO). There was a strong correlation between the distribution of juvenile with DO (R^2=0.85) and adult with DO (R^2=0.86). However, opposite trend was observed for distribution of PL with DO with R^2=0.81. This result showed that distribution of PL decreased with decreasing DO (Figure 6). However, the relationship between distributions of all life stages of freshwater prawns PL, juvenile and adult with temperature were weak with R^2 value 0.39, 0.38 and 0.47 respectively (Figure 7).

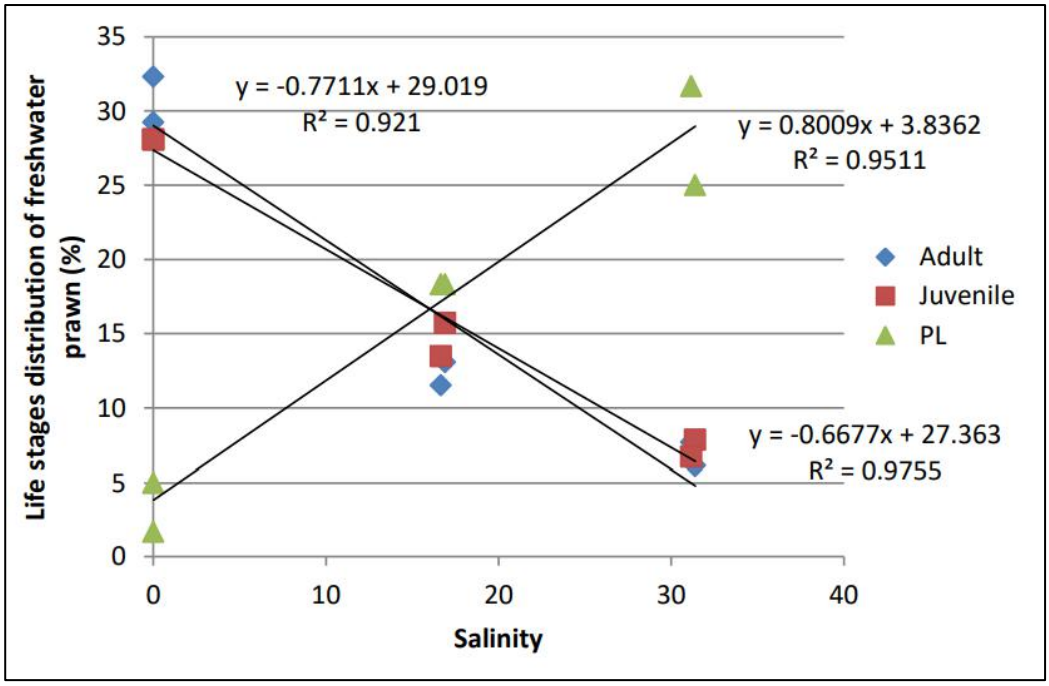


Fig 4 : Correlation of life stages of freshwater prawns, Macrobrachium spp. and salinity along the Petagas River.

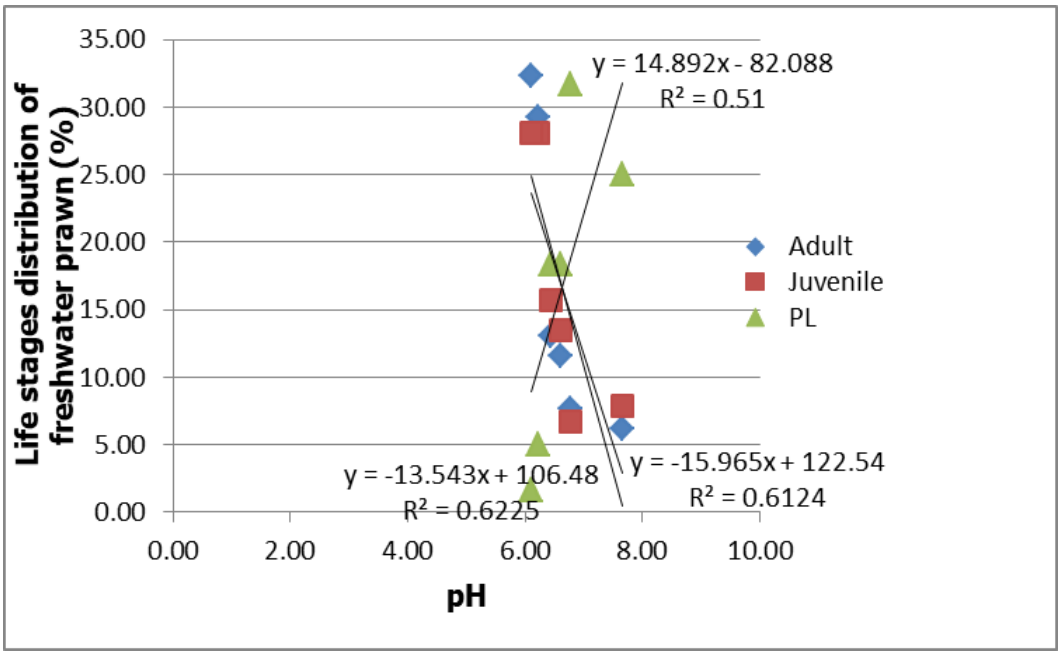


Fig 5:Correlation of life stages of freshwater prawns, Macrobrachium spp. and pH along the Petagas River.

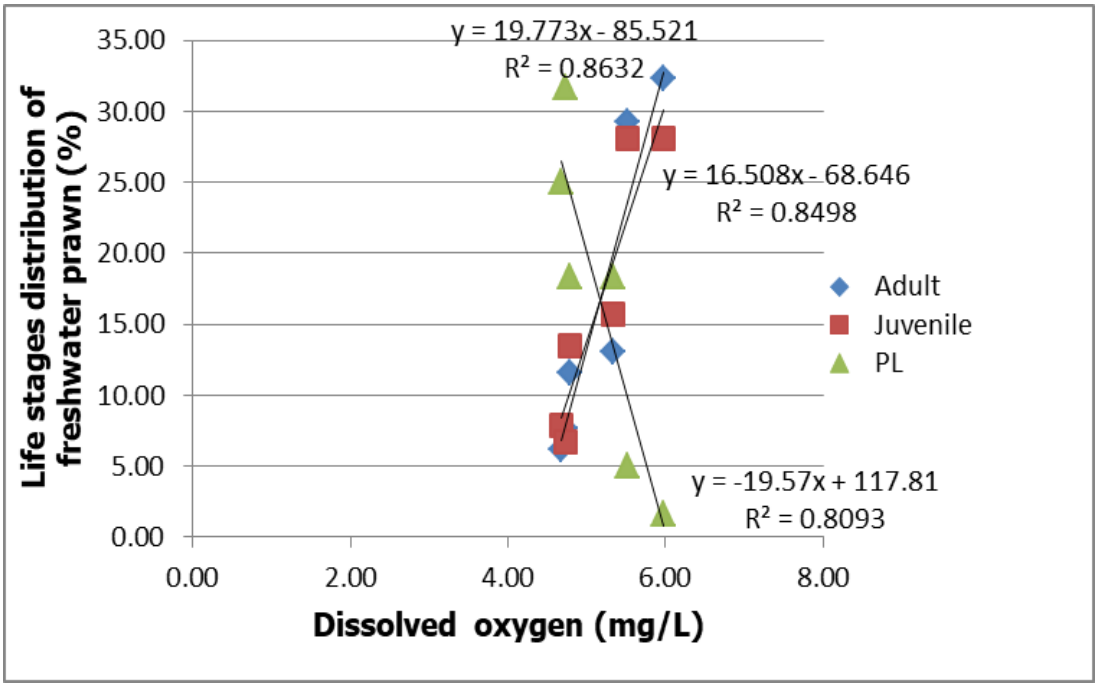


Fig 6: Correlation of life stages of freshwater prawns, Macrobrachium spp. and dissolved oxygen (DO) along the Petagas River.

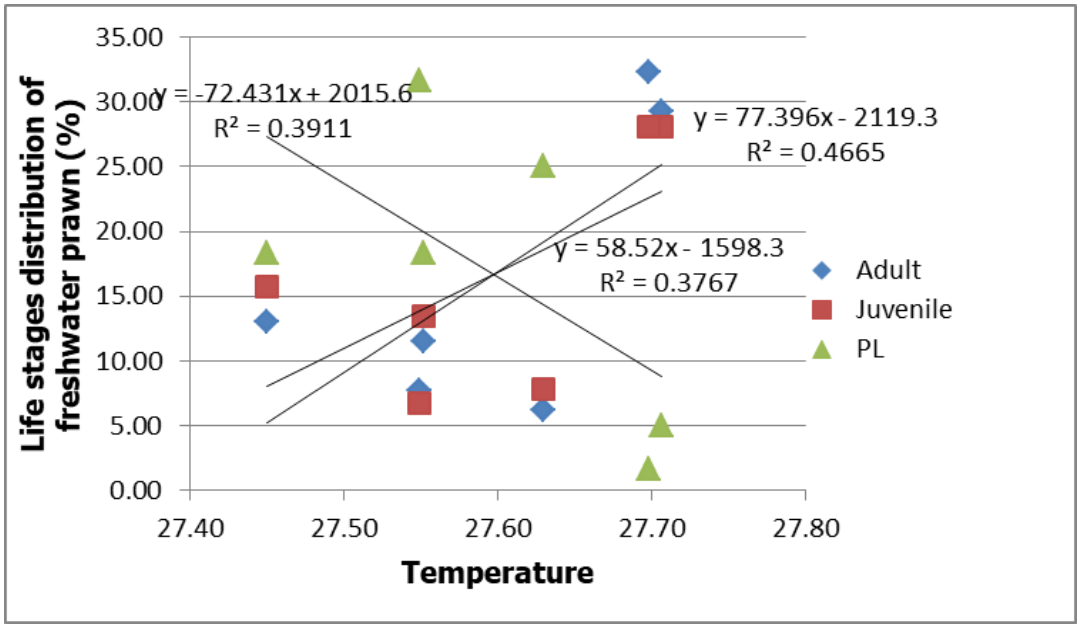


Fig 7: Correlation of life stages of freshwater prawns, Macrobrachium spp. and temperature along the Petagas River.

Trend of Catch per Unit Effort (CPUE) of Freshwater Prawns following Stocking Programme

The cumulative stocking of juvenile freshwater prawn in September 2013, February 2014, December 2014 and May 2015 were 21,000, 24,000, 27,300 and 37,300 individuals respectively (Table 1). The values of CPUE of different life stages of freshwater prawn were determined throughout the stocking programme. The mean values of CPUE of PL, juvenile and adult were 0.50, 0.74 and 5.42 prawn $trap^{-1}day^{-1}$ respectively. The CPUE of PL from September 2013, February 2014, December 2014 and May 2015 were 0.30, 0.30, 0.63 and 0.77 $trap^{-1}$ day^{-1} respectively. Meanwhile, the CPUE of juvenile and adult from the same time periods were 0.50, 0.53, 0.63 and 1.3 $trap^{-1}$ day^{-1} and 4.06, 5.5, 5.89 and 6.22 $trap^{-1}$ day^{-1} respectively. The result showed that the CPUE of PL, juvenile and adult were positively correlated with the increase of stocking juvenile following stocking programme with R^2=0.89, R^2=0.73 and R^2=0.87 accordingly (Figure 8).

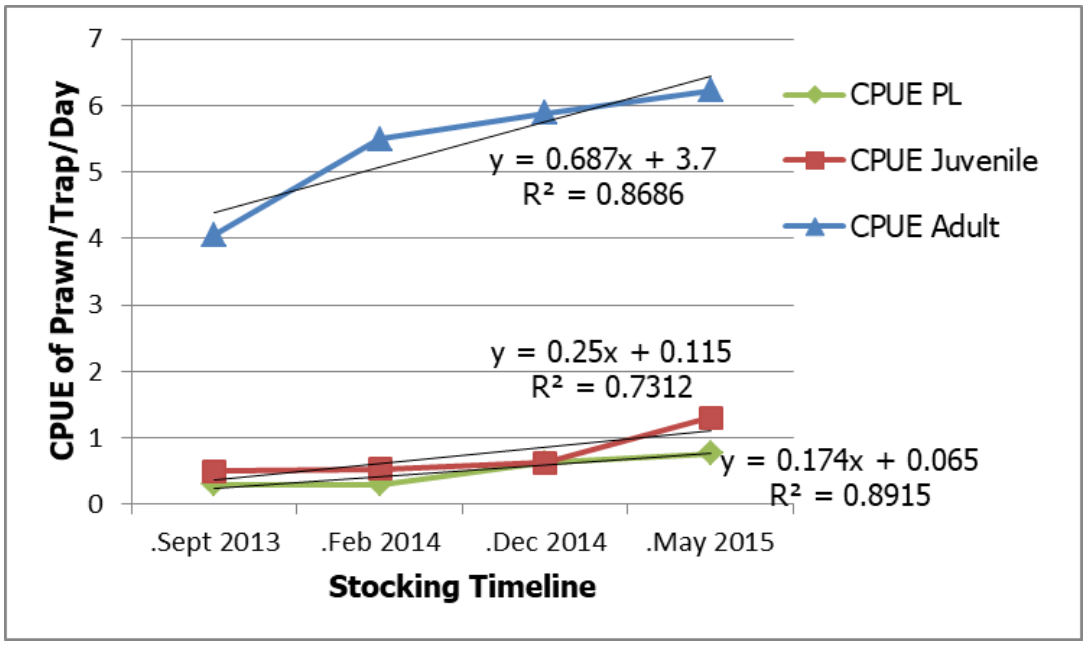


Fig 8 : Correlation in CPUE of different life stages of freshwater prawn, Macrobrachium spp. following stocking timeline in Petagas River.

IV. DISCUSSION

Distribution and Abundance of Genus Macrobrachium

The freshwater prawn is widely distributed along the Petagas River suggest that the species has great adaptation ability (Araújo and Valenti, 2007; Odinetz- Collart, 1991). Throughout their life cycle, the freshwater prawn is exposed to a wide range of salinities from 0–18 ppt (Limpadanai and Tansakul, 1980; Cheng *et al*., 2003). The gravid females migrate from upstream river to estuary where eggs hatch and larvae developed (Ismael and New, 2000).

The abundance of PL was found to be highest at the downstream region (30.99±1.02 ppt) of Petagas River as compared to mid-stream and upstream region of the river. The relationship of PL distribution in Petagas River was also directly correlated with salinity as the distribution increased with increasing salinity. This present study supports the previous study carried out in three rivers of Paikgacha, Bangladesh where number of *M. rosenbergii* PL increasing as the salinities increased along the river (Khair *et al*., 2000). Sandifer *et al*. (1975) also proved that tolerance of PL *M. rosenbergii* to gradual and rapid increases in salinity around 25 ppt to 30 ppt. However, the PL of genus *Macrobrachium* was found to be absence in study carried out by Arshad *et al.* (2011) in the estuary of Sungai Pulai, Johor. This suggests that not every river existed as habitat of *Macrobrachium* spp.

In laboratory condition, survival rate of PL stages increased as the salinity increasing. Zafar *et al*. (2015) found that survival rate of *M. rosenbergii* PL was 34.42% in high salinity (12 ppt) compared to low salinity (8 ppt) with 20% survival rate. Willführ-Nast *et al*. (1993) reported higher survival rates of *M. rosenbergii* at 14 to 25 ppt compared to less than 14 ppt. Previous study in laboratory condition reported that PL of *M. rosenbergii* can tolerate salinity. These results show that saline salinity is better for larval to post larval stages then post larvae converted slowly and gradually on 0 ppt (Zafar *et al.*, 2015). Larval studies of *Macrobrachium* sp. showed that larvae require saltwater for growth development and survival, whereas molting process

occurs in fresh and saltwater (Dugan, 1971; Dugan *et al*., 1975; Zafar *et al*., 2015). Therefore, it is clear that *Macrobrachium* prawns require conditions of constant saline water for successful development beyond stages VII and VIII until metamorphosis into PL (Ling and Merican, 1961; Uno and Kwon, 1969; Takano, 1987; Nandlal and Pickering, 2006).

According to Bauer and Delahoussaye (2008), the larvae undergo metamorphosis into PL and tend to be a benthic organism. At this stage, they migrate upstream towards freshwater to grow into juvenile prawn and finally becoming mature adult (Kriengkrai, 2006; John, 2009). During this time, juveniles may delay swimming upstream when hindered by stronger currents. The pattern is similar with results reported by Ling (1969) where the newly settled juveniles migrated from the estuary to the upstream region of river for their next phase of their life cycle. In *M. rosenbergii* from Southeast Asia, the juveniles began to swim upstream on 14th day after settlement (Ling, 1969). The present study showed that the juvenile size at the upstream region of Petagas River was larger (22.5±0.41 mm TL) than juvenile at the downstream region (18.2±0.28 mm TL), indicating the juveniles are growing as they migrate upstream of the river towards less saline water. The present result is supported by study from Atchafalaya River, Lousiana, USA, where the comparison between the carapace length of *Macrobrachium* sp. juveniles from upstream region and downstream region of the river showed significant different in sizes (Bauer and Delahoussaye, 2008).

Correlation between Abundance of Macrobrachium spp. with Water Parameters

The present study showed that PL of freshwater prawn increased with increasing pH value. This is in agreement with previous study showed survival rate of PL was higher at pH 6 than 5 in laboratory condition (Chen and Chen, 2003) while in wild, PL of was found highest at pH 8.0-8.5 (n>80) compared to lower pH 7.2-7.9 (n<80) at river in Bangladesh (Khair *et al*., 2000). Despite of some low and high pH values, it probably did not affect the distribution of PL in wild environment of Petagas River because the present study is in agreement with previous studies where pH ranging from 7.0-8.5 is known to be optimum for growth of *M. rosenbergii* (New, 1995; Khair *et al*., 2000, Chen and Chen, 2003 and Kawamura *et al*., 2015).

Negative correlation was found as PL distribution decreased with increasing DO. Low DO adversely affects the behaviour and normal physiology of crustaceans, such as the survival, respiration and circulation, feeding, metabolism, growth, and molting of penaeid shrimps (Cheng *et al*., 2003). In contrast with previous study carried out in laboratory condition, PL of *M. rosenbergii* were found to tolerate at more than 5 mg/L i.e 7.5 mg/L (Tidwell *et al*., 1998), 7.7± 0.1 mg/l (Tidwell *et al*., 2003) and 8.3 ± 0.2 mg/l (Tidwell *et al*., 2004). However, in most crustaceans including *M. rosenbergii*, a specific adaptive mechanism has developed, including behavioral and physiological responses, to cope with fluctuations in DO of the medium or even to hypoxic conditions (Johnson and Uglow, 1987; Charmantier *et al*., 1994; Morris and Butler, 1996; Chen and Kou, 1998). The correlation between distribution of PL and temperature of Petagas River was weak and had no significant difference with stations ($p>0.05$). The temperature was within the acceptable ranges 25.83 °C to 28.74 °C (Narejo *et al*., 2010; Abdul *et al*., 2014).

There were strong inversely positive correlations between the distribution of juvenile and adult freshwater prawn with salinity in Petagas River with R^2 value 0.98 and 0.95 respectively. Nina-Maryam and Anton (2015) reported the same trend of higher abundance of juvenile distribution (118.4 individuals/m^2) at the same river with salinity of 0 ppt while lower (2.6 individuals/m^2) at higher salinity. This finding is also in agreement with the previous study where the distribution and abundance of juveniles and adults freshwater prawn were highest (n>80 per sampling period) at low salinity ranging from 0 to 19 ppt (George, 1969; Ling, 1969; Khair *et al*., 2000; Montoya, 2003; De Silva and Funge-Smith, 2005).

In laboratory condition, previous studies showed that survival rate of juvenile and sub-adult of *M. rosenbergii* varied between 91% (at 0 ppt) and 78% (at 20 ppt) as the prawns grew and survived satisfactorily at 0–15 ppt salinities while decreasing as salinity increased, implying that the species can survive at wide salinity range (Limpadanai and Tansakul, 1980; Cheng *et al*., 2003; Chand *et al*., 2015). Results of this study also indicated juveniles and adult of *M. rosenbergii* occur naturally in estuarine areas of Petagas River are thus adapted to an environment in which salinity levels vary constantly and it supports that the species exhibits a wide tolerance to abrupt changes in salinity (George, 1969; Ling 1969; Chand *et al*., 2015).In contrast, the juvenile and adult of freshwater prawn, *M. rosenbergii* were found at range of salinity 2.1 to 8.7 ppt in Pumba River (John, 2009). These variations and differences of different life stages distribution may occur because of different environmental conditions such as local vegetation and food availability at the area and geographical locations. For example, the presence of adult individuals of *M. acanthurus* and *M. carcinus* were mainly found in coastal area (Mejía-Ortíz *et al*., 2001) while the absence in migration of adult *M. nipponense* from upstream to downstream was observed in study by Mashiko (1990). In the present study, besides can tolerate with wide range

salinities, the environmental factors such as geographical and availability of vegetation in the mid-stream and upstream region of Petagas River contributed to the distribution and abundance of the juveniles and adult prawn compared to downstream region.

The distribution of juveniles and adult prawns were found to be negatively correlated with pH in the present study, where number of juveniles and adult decreased with increasing pH. In contrast, Khair *et al*. (2000) found that at lower pH, lesser number of juveniles (n<80; pH 7.0-7.9) and adult (n<80; pH 7-8-7.9) were caught while more juveniles (n>80; pH 7.8-8.1) and adult (n>80; pH 7.1-8.5) of *M. rosenbergii* and a greater number of juveniles and adult (n>80; pH 8.0-8.5) were caught at higher pH. The survival rate of juveniles *M. rosenbergii* also was found increasing at higher pH compared to lower with pH 8.2 (100%) 7.4 (88.9%) 6.2 (94.4%) and 5.6 (94.4%) respectively (Kawamura *et al*., 2015). Out of all, despite of some low and high pH values, it probably did not affect the distribution of juveniles and adults in wild environment of Petagas River because the present study is in agreement with previous studies where pH ranging from 7.0-8.5 is known to be optimum for growth of *M. rosenbergii* (New, 1995; Khair *et al*., 2000, Chen and Chen, 2003 and Kawamura *et al*., 2015).

The DO in the present study was found ranging within the acceptable ranges between 4.16 mg/L to 7.21 mg/L. The distribution of juvenile and adult freshwater prawns was found increased with increasing DO. Low DO adversely affects the behaviors and normal physiology of crustaceans, such as the survival, respiration and circulation, feeding, metabolism, growth, and molting of penaeid shrimps (Cheng *et al*., 2003). This trend was obviously opposite with distribution of life stages of prawns with salinity. This is because DO is strongly influenced by combination of physical, chemical and biological characteristics of the river (Quinn *et al*., 2005; Williams *et al*., 2000) including anthropogenic influences such as domestic areas, industry and agriculture (Jarvie *et al*., 1998). Downstream region of Petagas River is crowded with housing areas and industries. These factors may alter the concentration of DO at the downstream compared to upstream region, thus lower concentration of DO was found at downstream region.

In similarity, Chen and Kou (1998) reported that the juveniles and adult freshwater prawn *M. rosenbergii* can tolerate the exposure to 3.38 and 4.45 mg/L DO. Cheng *et al*. (2003) reported that *M. rosenbergii* could tolerate under 2.75 and 1.75 mg/L DO however with optimum survival at >5 mg/L. Generally different life stages of *M. rosenbergii* are mainly affected by wide range of salinity thus, presence of PL, juveniles and adults in Petagas River may vary at different DO concentration. Moreover, the distribution of juvenile and adult may not be affected much by DO since most crustaceans and *M. rosenbergii* experiences specific adaptive mechanism to DO (Johnson and Uglow, 1987; Charmantier *et al*., 1994; Morris and Butler, 1996; Chen and Kou, 1998).

Trend of CPUE following Stocking Programme

Comparison between the CPUE of all life stages of freshwater prawn in Petagas River before and after the stocking programme cannot be made since there was no initial sampling was done before the stocking programme thus, comparison was made based on the stocking timeline. The present study reported that the CPUE of all life stages of freshwater prawn increases with the progress of the stocking programme. There was a strong correlation between the CPUE of the three life stages of freshwater prawn i.e PL, juvenile and adult stages observed in this study, (R^2=0.89, R^2=0.73 and R^2=0.87 respectively) which could be concluded that the *Macrobrachium* spp. in Petagas River reproduces in the Petagas River and this promotes continuous recruitment (Silva *et al*. (2006). The result corroborates the previous studies found that an increase in CPUE of *Macrobrachium* spp. PL and juveniles in the same river (Mariam-Syarmilah and Anton, 2016; Nina-Maryam and Anton, 2015; Aqilah-Musfirah and Anton, 2014).

The success of the stock enhancement programme was proven affected by the size of water body of the river (Choonhapran *et al*., 2003; De Silva and Funge-Smith, 2005). In the present study, although the total number of released juveniles was lower compared to previous studies, however the value is still considered sufficient by comparing the number of juveniles released per area of the rivers. The Petagas River covering 3.16 km^2 with a total number of released juveniles of *M. rosenbergii* was approximately 13,200 juveniles/ km^2. Choonhapran *et al*. (2003) reported a stock enhancement in Pak Phanang River, Thailand covering 422 km^2 with a total number of released juveniles of *M. rosenbergii* was approximately 165,000 juveniles/ km^2. Another stock enhancement of *M. rosenbergii* in *Sungai Perak* reported the total number of released juveniles was 132 juveniles/ km^2. It is clear that in order to determine the success of the stock enhancement programme, the total amount of released juveniles alone does not matter, but the area of the rivers or reservoirs need to be considered too.

The main goal of stock enhancement is to build a larger population of the organism to support the local landings on a sustainable basis by releasing the cultured organisms into the river, sea and lakes to conserve, enhance, or restore the fisheries resources (Mustafa, 2003; Bell *et al*., 2006; Lorenzen, 2008). Therefore, based on the result of the present study, the positive recruitment of CPUE of various life stages of freshwater prawn, *Macrobrachium* spp. in

Petagas River have indicated improvement in its population. The established *Macrobrachium* spp. and increase in its CPUE at the end of the stocking programme also proven that the releasing species started to establish in its population showing a positive sign of stock enhancement programme. Maidin *et al*. 2017 has proven that there were close genetic distances between the broodstock prawns in hatchery involved in the stocking programme and the sample prawns in the same river which reflects the success of the establishment of the prawn in the river. Choonhapran *et al*. (2003) has also reported that there will be in increased production of target species as the stocking programme increases.

A study by Silva *et al*. (2006) found that of *Macrobrachium* spp. did not show variations in the modes or mean length of the prawn caught throughout the year because due to continuous reproduction, which helps the continuous recruitments in the population over time. This pattern also can be seen in *M. amazonicum* juveniles (Sousa *et al*., 2013) and *M. jelskii* (Lima *et al*., 2006) at Amazon estuaries in Brazil. In contrast, the results differed from Bialetzki *et al*. (1997) where the *M. amazonicum* in the state of Paraná, southern Brazil showed recruitment occurred in rainy season only but not throughout the year. The recruitment patterns and CPUE of the stocking species may vary in different species, localities and geographies. It may also be affected by other factors including temperature (Shoji *et al*., 2011) conductivity, clarity, habitat complexity, river flow and species behaviour patterns (Dutterer *et al*., 2012; Bayley and Austen, 2002; Reynolds, 1996; Hilborn and Walters, 1992).

V. CONCLUSION

The finding suggests that the distribution and abundance of *Macrobrachium* spp. varies along Petagas River as its life stages tend to adapt and survive in a wide range of salinity, pH, DO and temperature like other undisturbed river in previous studies. The CPUE of PL, juvenile and adult prawns were positively correlated with the increased stocking juvenile following stocking programme. In the present study, the population *Macrobrachium* spp. has started to establish and showed positive sign of natural recruitment following the stocking programme. It showed that *Macrobrachium* spp. is able to live and adapt in the Petagas River. This study offers suggestive evidence for stock enhancement to be carried out more by fisheries managers in Petagas River as increasing numbers of juveniles released will improve the natural recruitment of the stocking species. Continued study is needed to explore the whole Petagas River area to better characterize the *Macrobrachium* spp. distribution and abundance in the river ecosystem and evaluate the effectiveness of the stock enhancement programme practices. Study on long term genetic impacts on stocking species following stock enhancement also would be one of the mechanisms in assessing the stocking programme. In Petagas River, it is expected that the recruitment rate of the enhanced stock would then significantly increase after years of stocking programme. If successful, the re-establishment of a self-sustained prawn population could serve as an indicator of a healthy environment, at least for the Petagas ecosystem. This study will provide baseline information on the stock enhancement programme in Malaysia as to the best knowledge of this study, this is the first record of stock enhancement programme of target species *Macrobrachium* spp. in Sabah.

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Determination of the best cooking time and the characteristics of Nile tilapia *pepes* (an Indonesian traditional fish product) processed by microwave oven

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Abstract— *The present study aimed to examine the best cooking time of Nile tilapia pepes processed by the microwave oven and to observe its chemical characteristics. The research was conducted in two stages. The treatment in the first stage was pepes cooking time which consists of four levels. The observed parameter was pepes sensory using multiple comparison tests. The experimental design to determine the chemical characteristics of pepes in the second stage was Completely Randomized Design with three levels namely raw, steamed, and microwave oven pepes in three replications. The observed parameters were moisture content, protein, amino acids, and free fatty acid levels. The result shows that the best cooking time of pepes with a microwave oven was five minutes. Analysis of variance showed that cooking affected the total selected essential amino acid and 14 kinds of amino acids content that were analyzed, namely aspartic acid, glutamic acid, serine, histidine, threonine, arginine, alanine, tyrosine, methionine, valine, phenylalanine, isoleucine, leucine, and lysine content of pepes but not significantly affected on the moisture content, protein, glycine and free fatty acids content of pepes. The total selected essential amino acid and 14 kinds of amino acids content of raw pepes were significantly different to cooked pepes (microwave oven and steamed pepes), but the total selected essential amino acid and 14 kinds of amino acids content of microwave oven pepes were not significantly different to steamed pepes. The chemical characteristics of microwave oven pepes were 73.04% WB of moisture, 67.95% DB of protein, 28.48% DB of total selected essential amino acids, and 7.22% in oil of free fatty acids content.*

Keywords— ***Nile Tilapia, Microwave Oven, Steaming, Pepes, Amino Acid.***

I. INTRODUCTION

Nile tilapia (*Oreochromis niloticus*) is a cultivable fish whose availability is not affected by the season. Nile tilapia is a potential local foodstuff in Indonesia. Based on the Data, Statistics, and Information Center of the Secretariat General of the Ministry of Maritime Affairs and Fisheries of the Republic of Indonesia in 2022, tilapia is a fish commodity with the highest production in aquaculture in Indonesia in the first quarter of 2022, namely 258 thousand tons (Kementerian Kelautan dan Perikanan, 2022).

Nuryanto *et al.* (2022) wrote that Nile tilapia has a high nutrient content, especially protein, calcium, and monounsaturated fatty acids. High nutrient content in Nile tilapia is proteins, calcium, oleic fatty acids, palmitic,

linoleic, and stearic acids, with 18.46 g, 74.38 g, 8.13%, 7.87%, 3.67%, and 4.30%, respectively. The most considerable amino acid content is aspartic acid, glutamic acid, lysine, arginine, and leucine, namely 2.16%, 3.45%, 1.84%, 1.88%, and 1.69%, respectively. Nile tilapia can be processed into various products and dishes such as fish *pepes. Pepes* is an Indonesian traditional fish product made of fish and spices, wrapped with banana leaves and then cooked by steaming for 30 minutes (Liuhartana, Priyanto and Hamzah, 2013).

Microwaves are a form of non-ionizing electromagnetic radiation with a frequency higher than regular radio waves but lower than infrared light. Microwaves relate to electromagnetic waves in the 300 to 300,000 MHz of frequency range. The microwave oven heats food by passing microwave radiation through it. The penetration depth of microwaves is dependent on food composition. Lower microwave frequencies with longer wavelengths have a more penetrating effect. The microwave oven may use less energy for cooking or reheating small amounts of food than a cook stove. Although microwave ovens are touted as the most efficient appliance, the energy savings are primarily due to the reduced heat mass of the food container (Bordoloi and Ganguly, 2014). In general, microwave processing is time-saving, energy-efficient, and yields good quality fish products with high nutritional value. Microwave cooking or blanching does not change the nutritional composition of fish (Viji *et al.*, 2022).

This study investigated the best cooking time and the influence of microwave processing on the chemical characteristics of *pepes* (moisture content, protein, amino acids, and free fatty acid levels). Cooking *pepes* with microwave oven was presumed to decrease the heating time, therefore diminishing the nutritional content decline. The previous research (Liuhartana, Priyanto and Hamzah, 2013) concluded that the minimal cooking time of Nile tilapia *pepes* processed by a microwave oven is 5 min based on microbial total plate count (TPC), internal temperature, and visual observation.

II. MATERIALS AND METHODS

Raw Material

Fresh Nile tilapia (*Oreochromis niloticus*) with 250g ± 20% in weight, tamarind, shallot, garlic, red chili, salt, sugar, ginger, candlenut, turmeric, galangal, lemon grass, and banana leaves were purchased from the traditional market in Palembang, South Sumatera. The materials were brought to the WSTPHP Laboratory (Workshop Teknologi Pengolahan Hasil Perikanan) of The Fisheries and Marine Faculty of PGRI Palembang University in Palembang, South Sumatra. Fresh fish was eviscerated and descaled, then washed with tap water. Raw *pepes* were prepared according to a method of Liuhartana, Priyanto and Hamzah (2013).

Equipment

The equipment used in this study included scales, knives, commercial microwave oven (Sharp model R-2491N(W), 2450 MHz, 800 W), steamer pot, gas stove, digital thermometer (Krisbow KW06-308 digital thermometer, range temperature -40°C to 250°C), a set of laboratory equipment for chemical analysis including pipettes, Petri dishes, dishes, Kjeldahl flasks, volumetric flasks, distillation apparatus, HPLC (Shimadzu model 20A with ODS-2 Hypersil column), oven and desiccator.

Research Procedure

In the first stage of the research, one factor was studied, namely cooking time by the microwave oven, and consisted of three levels: 5 (T1), 6 (T2), and 7 minutes (T3) with three replications. The 5 min as the first level was determined based on the minimal cooking time found by the previous study (Liuhartana, Priyanto and Hamzah, 2013). In addition, the *pepes* were kept in a microwave oven for another 3 minutes before being removed to spread the heat in the *pepes* evenly. The observed parameter was pepes sensory using multiple comparison tests. The sensory test was conducted at the Sensory Laboratory, Faculty of Agriculture, Sriwijaya University in Palembang, South Sumatra, Indonesia.

The experimental design to determine the chemical characteristics of *pepes* in the second stage was Completely Randomized Design with three levels namely raw, steamed, and microwave oven *pepes* in three replications. The observed parameters were moisture content, protein, amino acids, and free fatty acid levels. The chemical tests were conducted at Integrated Laboratory, IPB Bogor University in Bogor West Java, Indonesia.

Chemicals and reagents

NaOH, Brij-30 solution, H_2SO_4, H_3BO_3, and selenium mixture were purchased from Merck. Amino acid standard solution, ortophthaaldehyde (OPA), was purchased from Sigma. All chemicals and reagents used in the present work were of high purity and analytical grade.

Samples Analysis

Multiple Comparison Test

The Multiple Comparison Test was done according to Setyaningsih, Apriyantono, and Sari (2010), with some modifications. The 25 trained panelists were involved in the sensory test. The standard sample is steamed *pepes* for 30 minutes, coded 'B'. The four samples that will be compared with the standard sample are steamed *pepes* for 30 minutes,

microwaved *pepes* for 5 minutes, 6 minutes, and 7 minutes. The four types of samples are coded using a random 3-digit number. Panelists were first asked to identify standard samples and compare the samples presented with standard samples. Then, the assessment was carried out sequentially on the parameters of color, aroma, texture, and taste using five comparison scales, namely significantly better than the standard sample (score = 5), better than the standard sample (score = 4), as good as the standard sample (score = 3), worse than the standard sample (score = 2), significantly worse than the standard sample (score = 1). Finally, the panelists wrote the assessment results on the prepared questionnaire sheet.

The data obtained from the multiple comparison sensory tests were converted into a score and tabulated. First, an Analysis of Variance (ANOVA) was carried out, followed by Duncan's Multiple Range Test for significantly different samples.

Water Content

Water content determination is based on the difference in sample weight before and after drying. An empty porcelain cup is heated in the oven for 1 hour at 105 °C. The cup is cooled in a desiccator and then weighed after it cools down. First, the empty weight of the cup is weighed. As much as 2-10 g of sample is weighed into the cup. The cup is heated in the oven at 105 °C for 4 hours, cooled in a desiccator, and the cup and sample are weighed. Next, the cup and sample are heated for 2 hours at 105 °C, cooled in a desiccator, and the cup and sample are weighed. Heating and weighing were done until the weight remained (AOAC, 2005).

The water content is calculated by the formula:

Water content (%)=$(W_1-W_2)/W_1 \times 100\%$

W_1 = initial sample weight (g)

W_2 = Sample weight after drying (g)

Protein Content

Protein levels were measured using the Kjeldahl method. First, as much as 0.1 g of the sample was weighed, then put into a 100 mL Kjeldahl flask, then 2 g of selen mixture and 10 mL of concentrated H_2SO_4 were added. The sample is heated over an electric heater or Bunsen burner until it boils and the solution becomes clear greenish and then left to cool. The 10 mL of sample was then put into the distillation apparatus, and added 150 mL of distilled water and 50 mL of 40% NaOH, and then distilled. The distillation results were collected in an Erlenmeyer containing 10 mL of 2% H_2BO_3 solution, then titrated with 0.1 N HCl. The blank solution was analyzed like the sample (AOAC, 2005).

Calculation of protein levels is calculated by the formula:

Protein content (%) = $((V_1-V_2)\times N\times 0.014\times fk)/W\times 100\%$

W = sample weight (g)

V_1 = volume of 0.1 N HCl used in sample titration (mL)

V_2 = volume of 0.1 N HCl used in titration blank (mL)

N = normality HCl (0.1 N)

fk = conversion factor for protein from food in general = 6.25, for *pepes* = 6.25

Amino Acid Content

Amino acid analysis was carried out in the following stages. First, the hydrolyzed sample was dissolved in 5 mL of 0.01 N HCl and then filtered through millipore paper. Next, potassium Borate Buffer pH 10.4 was added in a 1:1 ratio. Next, a total of 10 µL of the sample was put into a clean empty vial, and added 25 µL of OPA reagent was left for 1 minute to complete the derivatization. Finally, as much as 5 µL of the 3rd step sample was injected into the HPLC column and then waited until all amino acids were separated. The time required is about 25 minutes (AOAC, 2005).

The percentage of amino acids in the sample can be calculated by the formula:

AA (%) = (µmol AA × Mr AA)/(µg sampel) × 100%

AA = Amino acids

Mr AA = Molecular weight of amino acids: Asp = 133.1; Glu = 147.1; Ser = 105.1; His = 155.2; Gli = 75.1; Thr = 119.1; Arg = 174.2; Ala = 89.1; Tyr = 181.2; Met = 149.2; Val = 117.1; Phe = 165.2; Ile = 131.2; Leu = 131.2; Lys = 146.2.

Free Fatty Acid Content

The level of free fatty acids in fat is determined by the following steps. First, the sample in the form of fat to be tested was weighed as much as ± 1 g in a 125 mL Erlenmeyer. Next, the sample was added with 50 mL of PA ethanol solvent containing pp indicator and shaken until the oil or fat dissolved. Finally, the solution was titrated with 0.1 N NaOH solution from a 10 mL burette with a calibration of 0.05 mL, and a blank was performed with every two or three titrations. The endpoint's color is a light pink that does not fade after 5-10 minutes (SNI 01-2352-1998).

Free fatty acid levels are calculated by the formula:

Free fatty acid content (% in oil) = $(V\times N\times M)/W\times 100\%$

V = Volume of NaOH for sample titration (sample - blank) (ml)

N = Normality of NaOH solution (0.1 N)

M = Molecular weight of dominant acid (oleic acid 282)

W = Sample weight (mg)

Statistical analysis

1. Parametric Statistical Analysis of Sensory Test Data

The data from the multiple comparisons sensory tests were converted into a score and tabulated. An analysis of variance or ANOVA (Analysis of Variance) was carried out, followed by Duncan's Multiple Range Test or Duncan's Significant Distance Difference for significantly different examples.

2. Parametric Statistical Analysis

The data was calculated using a completely randomized design (CRD) with the treatment of *pepes* cooking methods consisting of 3 levels (raw *pepes*, steamed *pepes*, and microwave *pepes*) with 3 replications. The data is further processed using analysis of variance or ANOVA (Analysis of Variance). Significance in the analysis of variance was carried out by comparing the F-table at 5% and 1% tests. Duncan Multiple Range Test (DMRT) was carried out on significantly different samples to determine the effect of each treatment.

III. RESULTS AND DISCUSSION

Determination The Best Cooking Time of Nile Tilapia *Pepes* Processed by Microwave Oven

Through the multiple comparison tests, panelists were asked to assess the differences in color, aroma, texture, and taste between each *pepes* served with standard *pepes*. Standard *pepes* are *pepes* that are steamed for 30 minutes, while other pepes are *pepes* that are microwaved for 5 minutes, 6 minutes, and 7 minutes (Figure 1.)

1. Color

The results of the multiple comparison tests on the color attribute of *pepes* in general panelists gave the lowest score in treatment B_0 (*pepes* cooked by steaming for 30 minutes) with an average rating of 2.88 while the highest score was in treatment B_1 (*pepes* cooked with a microwave oven for 5 minutes) is 3.12. The average panelist assessment of *pepes* color is shown in Figure 2. The analysis of variance showed that cooking *pepes* in a microwave oven had no significant effect on the color of *pepes* produced.

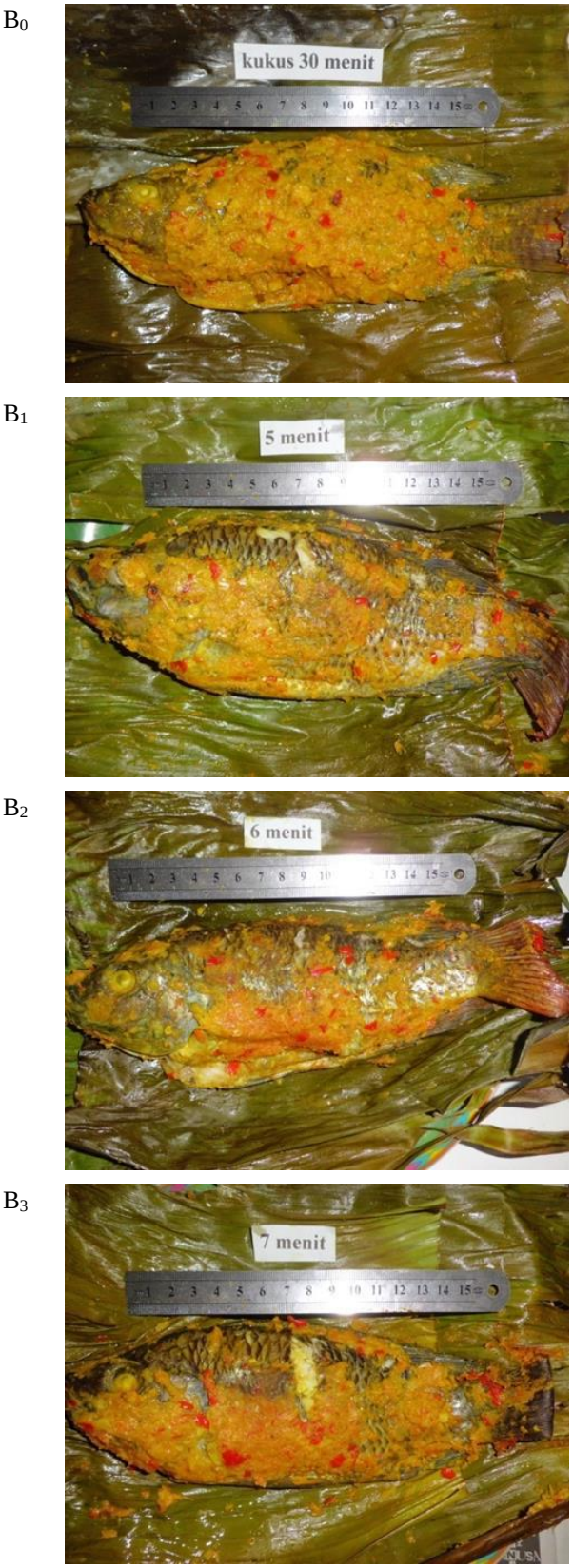

Fig.1. Nile tilapia pepes. B_0 = steamed pepes for 30 minutes, B_1 = pepes in the microwave for 5 minutes, B_2 = pepes in the microwave for 6 minutes, B_3 = pepes in the microwave for 7 minutes. The picture above with a ruler length comparison of 15 cm.

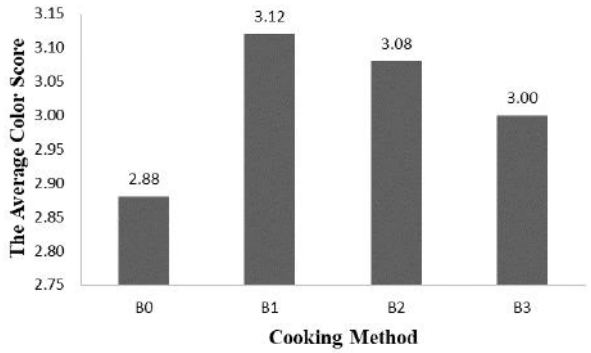

Figure 2. Multiple comparison test of pepes color. B_0 = steamed pepes for 30 minutes, B_1 = pepes in the microwave for 5 minutes, B_2 = pepes in the microwave for 6 minutes, B_3 = pepes in the microwave for 7 minutes. Analysis of Variance (ANOVA) showed no significant differences between samples.

2. Aroma

The results of the multiple comparison tests on the aroma attribute of *pepes* in general, the panelists gave the lowest score in treatment B_2 (*pepes* cooked in a microwave oven for 6 minutes) with an average rating of 2.88 while the highest score was in treatment B_1 (pepes cooked in an oven microwave for 5 minutes) is 3.24. The average panelist's assessment of the aroma of *pepes* is presented in Figure 3. The analysis of diversity showed that cooking *pepes* in a microwave oven had no significant effect on the aroma of *pepes*.

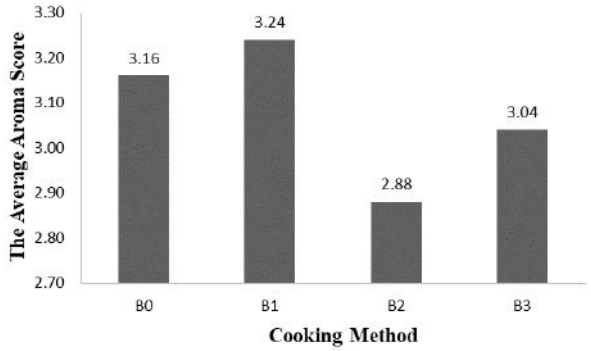

Fig.3. Multiple comparison test of pepes aroma. B_0 = steamed pepes for 30 minutes, B_1 = pepes in the microwave for 5 minutes, B_2 = pepes in the microwave for 6 minutes, B_3 = pepes in the microwave for 7 minutes. Analysis of Variance (ANOVA) showed no significant differences between samples.

3. Texture

The results of the multiple comparison test for the texture attribute on *pepes* in general, the panelists gave the lowest score in treatment B_2 (*pepes* cooked in a microwave oven for 6 minutes) with an average rating of 2.92 while the highest score was in treatment B_3 (*pepes* cooked in an oven microwave for 7 minutes) is 3.40. The average panelist assessment of the color of the *pepes* is presented in Figure 4. The results of the analysis of diversity showed that cooking *pepes* in a microwave oven had no significant effect on the texture of *pepes* produced.

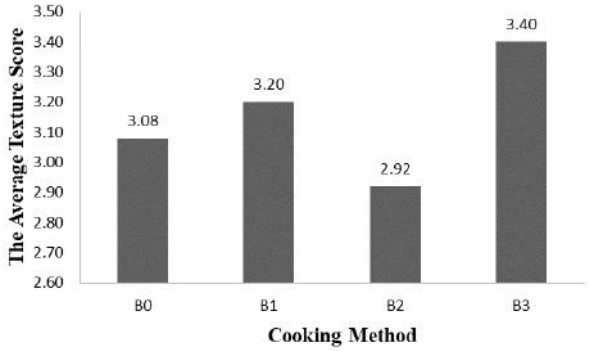

Fig.4. Multiple comparison test of pepes texture. B_0 = steamed pepes for 30 minutes, B_1 = pepes in the microwave for 5 minutes, B_2 = pepes in the microwave for 6 minutes, B_3 = pepes in the microwave for 7 minutes. Analysis of Variance (ANOVA) showed no significant differences between samples.

4. Taste

The results of the multiple comparison test for the taste attribute of *pepes* in general, the panelists gave the lowest score in treatment B_0 (steamed *pepes* for 30 minutes) and B_2 (*pepes* cooked in a microwave oven for 6 minutes) with an average rating of 3.04 while the value the highest was in treatment B_1 (*pepes* cooked in a microwave oven for 5 minutes) which was 3.56. The average panelist's assessment of the taste of *pepes* is presented in Figure 5. The analysis of variance showed that cooking *pepes* in a microwave oven had no significant effect on the color of *pepes* produced.

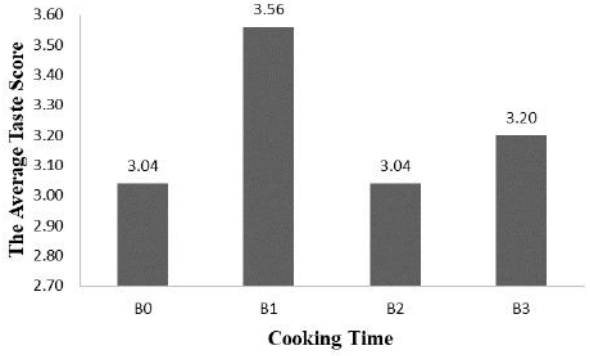

Fig.5. Multiple comparison test of pepes taste. B_0 = steamed pepes for 30 minutes, B_1 = pepes in the microwave for 5 minutes, B_2 = pepes in the microwave for 6 minutes, B_3 = pepes in the microwave for 7 minutes. Analysis of Variance (ANOVA) showed no significant differences between samples.

Cooking *pepes* in a microwave oven had no significant effect on the color, aroma, texture, and taste of *pepes*, which is supposed to be caused by the similarity in the conditions of products cooked in a microwave oven and steaming. However, the short duration of cooking in a microwave oven and the low air temperature on the product's surface cause the product to remain soggy (Yaylayan and Roberts, 2001). Cooking by steaming also causes the surface of the product to get wet due to moisture.

The conclusion from the first stage of the study is that the best time to cook *pepes* in a microwave oven is 5 minutes which is the shortest cooking time because the results of the analysis of variances show that cooking *pepes* in a microwave oven for 5 minutes, 6 minutes and 7 minutes has no significant effect on color, aroma, texture, and taste of *pepes* produced. The results of the first research stage were then used for the second research stage, namely determining the chemical characteristics of *pepes*.

Determination The Chemical Characteristics of Nile Tilapia *Pepes* Processed by Microwave Oven

The results of the second research stage, namely the best cooking time for *pepes* in a microwave oven for 5 minutes, were then used for the second research stage. Raw *pepes* and steamed *pepes* were also analyzed for comparison.

1. Water Content

Pepes water content ranges from 72.14% to 73.75%. The highest water content was in treatment C_0 (raw *pepes*), and the lowest concentration was in treatment C_1 (*pepes* steamed for 30 minutes). Cooking (steaming and microwaving) causes a decrease in the moisture content of *pepes*. The decrease in the water content of C_1 was more significant than that of C_2 (*pepes* cooked in a microwave for 5 minutes). The average moisture content of *pepes* from all treatments is presented in Figure 6. The analysis of variance showed that the cooking method had no significant effect on the moisture content of the *pepes* produced.

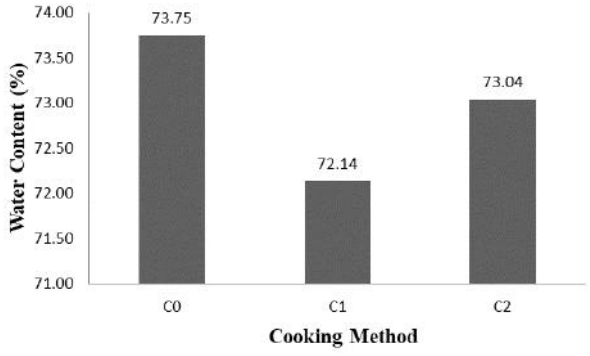

Fig.6. Multiple comparison test of pepes water content. C_0 = raw pepes, C_1 = pepes cooking by conventional method (steamed pepes for 30 minutes), C_2 = pepes in the microwave for 5 minutes. Analysis of Variance (ANOVA) showed no significant differences between samples.

A decrease in water content in steamed fish was also found in the study results of Ghelichpour and Shabanpour (2011) on golden gray mullet (*Liza aurata*) fillet, Dhanapal *et al.* (2012) on tilapia steaks (*Oreochromis mossambicus*), Devi and Sarojnalini (2012) on *Amblypharyngodon mola* and Aisyah (2012) on cobia fish (*Rachycentron canadum*) meat. In addition, a decrease in water content in fish cooked in a microwave oven was also shown by the results of research by Unusan (2007) and Asghari, Zeynali, and Sahari (2013) on rainbow trout fish fillets (*Oncorhynchus mykiss*) Weber *et al.* (2008) on silver catfish fillet (*Rhamdia quelen*).

Kusnandar (2011) explains that besides functioning as a source of nutrition, protein also has specific functional properties that can affect the characteristics of food products. Among these properties is its function for the absorption and binding of water. The heating process can cause protein denaturation, resulting in food ingredients losing their water-holding capacity. The higher the heating temperature, the lower the amount of bound water. The water content of *pepes* C_1 (steamed for 30 minutes), which was lower than the moisture content of *pepes* C_2 (microwave oven 5 minutes), was supposed to be caused by the heat received by *pepes* C_1, which was greater than that of *pepes* C_2. This causes *pepes* C_1 to lose more water content. Oduro, Choi and Ryu (2011) also showed a similar result on chub macherel (*Scomber japonicus*).

2. Protein Content

Pepe's protein content ranges from 65.55% (DB) to 70.05% (DB). The highest protein content was in treatment C_0 (raw *pepes*), and the lowest concentration was in treatment C_1 (*pepes* steamed for 30 minutes). Cooking causes a decrease in *pepes* protein levels. The decrease in protein content of C_1 was more significant than that of C_2 (*pepes* cooked in the microwave for 5 minutes). The average protein content of *pepes* from all treatments is shown in Figure 7.

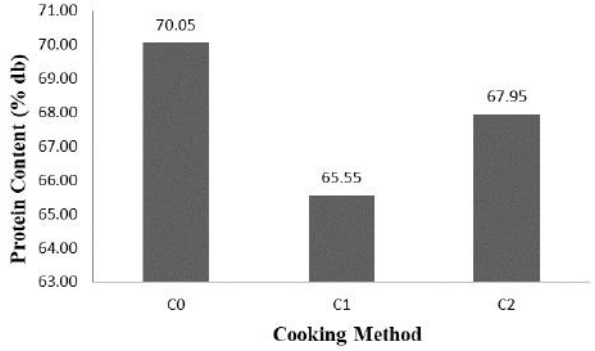

Fig.7. Multiple comparison test of pepes protein content. C_0 = raw pepes, C_1 = pepes cooking by conventional method (steamed pepes for 30 minutes), C_2 = pepes in the microwave for 5 minutes. Analysis of Variance (ANOVA) showed no significant differences between samples.

The analysis of variance showed that the cooking method had no significant effect on the protein content of the *pepes*. There was a decrease in the protein content of *pepes* from raw to cooked (steamed and microwaved), but the difference was not significant. The results of the research also show a decrease in protein content (% DB) due to steaming by Aisyah (2012) on cobia fish (*Rachycentron canadum*) meat. A decrease in protein content (% DB) in fish cooked in a microwave oven was also shown by the results of Asghari, Zeynali, and Sahari's (2013) research on rainbow throut (*Oncorhynchus mykiss*) filets.

The protein content of *pepes* C_1 (steamed for 30 minutes) was lower than the protein content of *pepes* C_2 (microwave oven 5 minutes), thought to be caused by the heating process for *pepes* C_1 which took longer than *pepes* C_2 (the steaming time for *pepes* was much longer than the cooking time for *pepes* in a microwave oven). The results of the research by Tapotubun, Nanlohy, and Louhenapessy (2008) showed that the protein content of fish decreased with increasing heating time. The longer the heating time, the smaller the water-soluble protein is lost along with the water that comes from the fish meat.

3. Amino Acid Content

The total levels of selected essential amino acids contained in *pepes* ranged from 19.05% DB to 28.48% DB. The highest concentration of selected total essential amino acids was in treatment C_2 (microwave oven 5 minutes), and the lowest concentration was in treatment C_0 (raw *pepes*). The highest amino acid in *pepes* was glutamic acid, and the lowest was histidine of the 15 amino acids analyzed. The amino acid content increases from raw *pepes* to cooked *pepes* (steamed and microwaved). The average levels of selected amino acids and essential amino acids in total *pepes* from all treatments are presented in Table 1.

The analysis of diversity showed that the cooking method had no significant effect on the glycine content of *pepes*. However, the diversity analysis showed that the cooking treatment method significantly affected the levels of the total selected essential amino acids and 14 other types of amino acids, which were analyzed in *pepes*.

The results of the Duncan Multiple Range Test (DMRT) showed that the total selected essential amino acids and 14 types of amino acids were analyzed, namely aspartic acid, glutamic acid, serine, histidine, threonine, arginine, alanine, tyrosine, methionine, valine, phenylalanine, isoleucine, leucine and lysine in treatment C_0 were significantly different from treatments C_1 and C_2. However, treatment C_1 was not significantly different from treatment C_2. In addition, the levels of total selected essential amino acids and 14 types of amino acids in raw *pepes* were significantly different from those of cooked *pepes* (microwave oven and steamed). However, the levels of total selected essential amino acids and 14 types of amino acids of *pepes* cooked in the microwave were not significantly different from steamed *pepes*.

The following studies also show the same results. Unusan (2007) stated that the content of essential amino acids and non-essential amino acids in rainbow throut (*Oncorhynchus mykiss*) meat increased significantly from raw to cooked condition but was not significantly different between fish meat cooked in a microwave oven and with a conventional oven. Research by Oduro, Choi, and Ryu (2011) on chub macherel (*Scomber japonicus*) soaked in salt solution concluded that there was a significant increase in the essential amino acid content of fish meat from raw to cooked conditions cooked by steaming, microwave ovens, frying, and roasting. The study also showed that glutamic acid is an amino acid with the highest levels in chub mackerel. Erkan, Ozden, and Selcuk (2010) stated that cooking by frying, roasting, and steaming causes a marked increase in the amino acid content of several marine fish. Apriyana (2011), who studied the long-pong snail (*Fasciolaria Salmo*), and Insanabella (2012), who studied the red-eyed snail (*Cerithidea obtusa*) stated that steaming causes an increase in amino acids.

Table 1. Amino acid profile of raw pepes, steamed pepes and microwave pepes

Amino Acid	C_0 (%DB)[2,3]		C_1 (%DB)[2,3]		C_2 (%DB)[2,3]	
Aspartic acid	4.61	a	5.73	b	5.75	b
Glutamic acid	7.37	a	10.57	b	11.42	b
Serine	1.78	a	2.55	b	2.74	b
Histidine*	1.12	a	1.62	b	1.73	b
Glycine	2.46		3.02		3.24	
Threonine*	1.94	a	2.90	b	3.06	b
Arginine*	2.97	a	4.20	b	4.47	b
Alanine	2.91	a	4.06	b	4.37	b
Tyrosine	1.42	a	2.08	b	2.18	b
Methionine*	1.35	a	1.90	b	2.06	b
Valine*	2.34	a	3.45	b	3.61	b
Phenylalanine*	1.98	a	2.98	b	3.13	b
Isoleucine*	2.22	a	3.30	b	3.47	b
Leucine*	3.57	a	5.05	b	4.98	b
Lysine*	3.81	a	5.65	b	5.90	b
Total selected essential amino acids[1]	19.05	a	27.22	b	28.48	b

C_0 = raw *pepes*

C_1 = konventional (steamed 30 minutes)

C_2 = microwave oven 5 menit

* = essential amino acids

[1] Sum of histidine, threonine, arginine, methionine, valine, phenylalanine, isoleucine, leucine and lysine

[2]Average of three replicates

[3]Every two means in one row that have the same letter are stated to be not significantly different at the 5% level.

The cooking process causes an increase in *pepes* amino acid levels. Fellows (2000) suggests that heat treatment is a significant cause of changes in the nutritional properties of foods. The heating process causes protein denaturation (Kusnandar, 2011), which results in the unfolding of protein coils so that peptide bonds can be broken (Almatsier, 2009). The heating process in food cooking creates conditions that make it easier for proteins to be hydrolyzed into free amino acids. Damodaran (1996) suggested that most food proteins are denatured when exposed to moderate heat treatment (60-90°C, 1 hour or less). Extensive denaturation of proteins often results in insolubility, which can impair the functional properties of proteins depending on their solubility. From a nutritional point of view, protein denaturation can increase the digestibility and bioavailability of essential amino acids. Moderate heating of purified vegetable protein and egg protein preparations improves their digestibility without creating toxic derivatives.

The levels of 14 types of amino acids in C_2 (*pepes* cooked in the microwave for 5 minutes) were higher than in C_1 (*pepes* cooked for 30 minutes), presumably because protein hydrolysis was more effective due to the influence of microwaves. Margolis, Jassie, and Kingston (1991) stated that amino acids, peptides, and proteins are charged molecules with dipolar properties. Proteins are composed of several dipolar moieties that contribute to the net dipole moment of the total protein, further modified by hydration shell molecules. Electromagnetic energy can increase the rotational energy of bonds connecting the dipolar moieties to nearby atoms, thereby reducing the energy required to break bonds and increasing the likelihood of hydrolysis processes. The combination of heating and possibly increasing the rotational energy of the peptide bonds can catalyze more effective peptide bond hydrolysis and maintain the integrity of the less stable amino acids. Chiou and Wang (1989) reported an improved method for analyzing amino acids using microwaves with a new and faster HPLC. Microwaves are used to hydrolyze proteins at the protein and peptide hydrolysate preparation stage. The research results of Margolis, Jassie, and Kingston (1991) showed that complete hydrolysis of proteins could be achieved by exposure to microwaves under controlled conditions. Hydrolysis can be achieved in a short time at relatively low temperatures. Besides providing a thermal effect, microwave radiation can also cause or facilitate the breaking of peptide bonds by local interactions with each polarized amide group of the peptide chain. The highest levels of glutamic acid, among other amino acids, cause a savory taste in *pepes*. Glutamic acid is an amino acid that can give a savory taste (Kusnandar, 2011).

4. Free Fatty Acid Content

Pepes-free fatty acid levels range from 7.25% in oil to 7.22% in oil. The highest levels of free fatty acids were in treatment C_0 (raw *pepes*), and the lowest was in treatment C_1 (*pepes* steamed for 30 minutes). The average levels of pipes-free fatty acids from all treatments are shown in Figure 8.

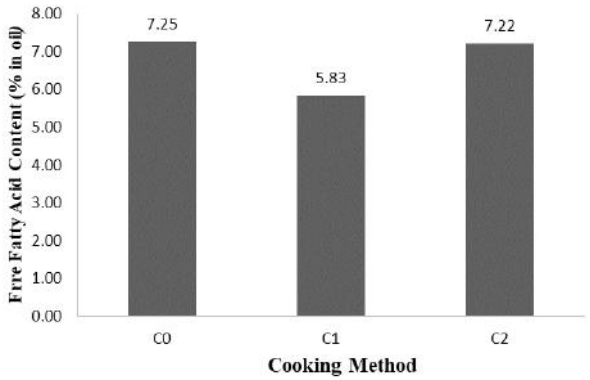

Fig.8. Multiple comparison test of pepes free fatty acid content. C_0 = raw pepes, C_1 = pepes cooking by conventional method (steamed pepes for 30 minutes), C_2 = pepes in the microwave for 5 minutes. Analysis of Variance (ANOVA) showed no significant differences between samples.

The analysis of variance showed that the cooking method had no significant effect on the levels of *pipes* free fatty acids produced. There was a decrease in free fatty acids from raw *pepes* to cooked (steamed and microwaved) *pepes*, but the difference was insignificant.

A decrease in free fatty acid levels due to cooking was also shown in a study by Weber *et al*. (2008) on silver catfish filet (*Rhamdia quelen*). Cooking with boiling, conventional baking, microwave baking, grilling, and deep frying with soybean oil, canola oil, and partially hydrogenated vegetable oil causes a decrease in free fatty acid levels in silver catfish filets. Weber *et al*. (2008) suggested that it was caused by the loss of volatile free fatty acids during cooking, or it could also be due to the deactivation of the lipase enzyme due to heating, thereby preventing the formation of free fatty acids in cooked fish.

The reaction of releasing free fatty acids from glycerin in the molecular structure of fat or the reaction of hydrolysis of fats or lipolysis can be triggered by the activity of lipase enzymes or heating, which causes the breaking of ester

bonds and the release of free fatty acids. Each release of one free fatty acid molecule requires one water molecule so that the hydrolysis reaction of fat can occur if there is water and heating (Kusnandar, 2011). The water in *pepes* comes from fish and spices.

The free fatty acid content of *pepes* C_1 (conventional, steamed 30 minutes), which is lower than the free fatty acid content of *pepes* C_2 (microwave oven 5 minutes), is thought to be caused by the heating received by *pepes* C_1, which is greater than *pepes* C_2 so that there are more volatile free fatty acids lost. More and more lipase enzymes are inactive. Deactivation of the lipase enzyme due to heating prevents the formation of free fatty acids.

Conclusions

Based on the research results obtained, conclusions can be drawn, namely (1) The best time for cooking *pepes* with a microwave oven is five minutes, (2) The cooking method has a significant effect on the total levels of selected essential amino acids and 14 types of amino acids analyzed, namely aspartic acid, glutamic acid, serine, histidine, threonine, arginine, alanine, tyrosine, methionine, valine, phenylalanine, isoleucine, leucine and lysine *pepes* but had no significant effect on water content, protein, glycine and free fatty acids *pepes*, (3) The levels of total selected essential amino acids and 14 types of amino acids for *pepes* would be significantly different from cooked *pepes* (microwave oven and steamed) but the levels of total selected essential amino acids and 14 types of amino acids for *pepes* cooked in microwave were not significantly different from steamed *pepes*, (4) The chemical characteristics of *pepes* are water content 73.75% DB, protein 70.05% DB, selected essential amino acids total 19.05% DB and content of free fatty acid 7.25% in oil. The chemical characteristics of the steamed *pepes* are 72.14% WB of water content, 65.55% DB of protein, 27.22% DB of total amino acids, and 5.83% free fatty acids in the oil. On the contrary, the chemical characteristics of *pepes* cooked in the microwave were 73.04% DB of water, 67.95% DB of protein, 28.48% DB of selected amino acids, and 7.22% in the oil of free fatty acids.

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Urban and peri-urban plastic bag pollution: producers' perceptions of the impacts of plastic bag ingestion by domestic ruminants in the commune of Dori in Burkina Faso

Pollution urbaine et péri-urbaine aux sachets plastiques : perceptions des producteurs liées aux impacts de l'ingestion des sachets plastiques par les ruminants domestiques dans la commune de Dori au Burkina Faso

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Abstract— *The phenomenon of pollution by plastic waste is a public health problem in Burkina Faso. The ingestion of these plastic bags by domestic ruminants causes enormous losses to producers. Thus, to have the involvement of these producers in the management of plastic, this study was initiated to collect their perceptions (knowledge, attitudes and practices) on this scourge of plastic ingestion by farm animals. It was conducted from May to June 2021 and involved 60 producers living in the urban and peri-urban area of the commune of Dori in Burkina Faso. The interviews focused on the characterization of their farms (breeding system, livestock diversity, animal feeding); their knowledge of the phenomenon of ingestion of plastic bags by domestic ruminants and its impact (mortality and loss of income) on farms; attitudes, practices against the scourge and their proposed solutions. The survey revealed that animal feed was based essentially on natural grazing at 77% with supplementation for a minority of farms (6%) ($p < 0.001$). In addition, the extensive system based on transhumance was the most widespread because it concerned 83% (50) of the producers ($p < 0.001$). The ingestion of plastic bags by the animals is perceived*

by the producers as one of the main causes of the mortalities recorded in their farms, however the causes seem to be external to the farming systems, in view of the solutions they recommend. Respondents know the symptoms of plastic ingestion (weight loss (43%), persistent bloating (31%) often accompanied by a hardening of the abdomen and diarrhea (13%), anorexia (12 %) and a runny nose (1%)), but which can be confused with other parasitic infections, and have traditional practices for diagnosing it. The study suggests that special measures be made for a better awareness of the management of plastic bags in the environment, with the support of environmental and public health technicians, municipal and communal authorities of Dori.

***Keywords*— commune of Dori, ingestion of plastic bags, perceptions, producers, domestic ruminants.**

Résumé *— Le phénomène de pollution par les déchets plastiques est un problème de santé publique au Burkina Faso. L'ingestion de ces sachets plastiques par les ruminants domestiques causent d'énormes pertes aux producteurs. Ainsi, pour avoir l'implication de ces producteurs dans la gestion du plastique, cette étude a été initiée pour récolter leurs perceptions (connaissances, attitudes et pratiques) sur ce fléau d'ingestion du plastique par les animaux d'élevage. Elle a été conduite de mai à juin 2021 et a porté sur 60 producteurs vivant dans la zone urbaine et péri-urbaine de la commune de Dori au Burkina Faso. Les interviews ont porté sur la caractérisation de leurs élevages (système d'élevage, diversité du cheptel, conduite alimentaire des animaux) ; leurs connaissances sur le phénomène d'ingestion des sachets plastiques par les ruminants domestiques et de son impact (mortalité et pertes de revenus) dans les élevages ; des attitudes, des pratiques face au fléau et de leurs propositions de solutions. L'enquête a révélé que l'alimentation des animaux était basée essentiellement sur le pâturage naturel à 77% avec une complémentation pour une minorité des élevages (6%) ($p < 0,001$). De plus, le système extensif basé sur la transhumance était le plus répandu car concernait 83% (50) des producteurs ($p < 0,001$). L'ingestion des sachets plastiques par les animaux est perçue par les producteurs comme une des principales causes des mortalités enregistrées dans leurs élevages, cependant les causes semblent être externes aux systèmes d'exploitation, eu égard des pistes de solutions qu'ils préconisent. Les enquêtés connaissent les symptômes de l'ingestion du plastique (amaigrissements (43%), les ballonnements persistants (31%) accompagné souvent d'un durcissement de l'abdomen et de la diarrhée (13%), de l'anorexie (12%) et d'un écoulement nasal (1%)), mais qui peuvent être confondants avec d'autres parasitoses, et ont des pratiques traditionnelles pour la diagnostiquer. L'étude suggère que des dispositions particulières soient prises pour une meilleure sensibilisation à la gestion des sachets plastiques dans l'environnement, avec l'appui des techniciens de l'environnement et de la santé publique, des autorités municipales et communales de Dori.*

***Mots clés*— commune de Dori, ingestion de sachets plastiques, perceptions, producteurs, ruminants domestiques.**

I. INTRODUCTION

L'utilisation de l'emballage plastique dans les industries agro-alimentaire a été considérée comme un mal nécessaire pour garantir la prévention des contaminations extérieures chimiques ou microbiennes. Relativement moins chers et très légers, l'utilisation des emballages plastiques connait une forte augmentation, du fait d'une forte croissance de la population humaine. Selon les dernières estimations de l'organisation de coopération et de développement économiques (OCDE), la production mondiale de plastiques est passée de 2 millions de tonnes/an en 1950 à plus de 460 millions de tonnes en 2019, générant 353 millions de tonnes de déchets dont moins de 10% sont actuellement recyclées et 22% sont abandonnées dans des décharges sauvages, brûlées à ciel ouvert ou rejetées dans l'environnement. Le même rapport alarme que sans l'adoption de politiques radicales pour lutter à l'échelle planétaire contre le plastique, la production de déchets triplera d'ici à 2060 (OCDE, 2022).

Les conditions climatiques et socio-économiques difficiles dans zones arides et semi-arides, conditionnent les éleveurs à privilégier les pâturages naturels communautaires comme source d'alimentation pour leur bétail (Zampaligré *et al*., 2013; Kouadja *et al*., 2018). Or ces pâturages sont sujets à la pollution, notamment aux sachets plastiques (Priyanka et Dey 2018). Ces déchets plastiques posent de plus en plus des problèmes environnementaux affectant les écosystèmes et la santé animale et humaine (Rhodes, 2018). Ces impacts négatifs incluent les dommages aux terres agricoles, à la faune, à la flore et plus en plus aux animaux d'élevage (Windsor *et al*., 2019; Stubenrauch et Ekardt, 2020). Chez les animaux par exemple, les problèmes plus aigus de toxicité observés se traduisent par une anorexie, une diminution de la

production et une perte progressive de l'état corporel voire à de fortes mortalités dans les troupeaux (Remi-Adewunmi *et al*., 2004 ; Tiruneh et Yesuwork, 2010).

A l'instar des autres pays d'Afrique, au Burkina Faso, les sachets plastiques sont considérés comme une solution à portée de main surtout pour emballer des objets et produits divers dont les aliments et produits alimentaires. Cependant, l'utilisation des sachets plastiques est réglementée au Burkina Faso par la loi N°017-2014/AN du 20 mai 2014 (https://www.informea.org/fr/node/182290). Cette réglementation visait à répondre aux inquiétudes des environnementalistes, notamment sur les conséquences sanitaires de l'usage de ces plastiques non biodégradables. Le plus grand risque n'est pas lié seulement à la pollution environnementale, mais également à l'ingestion de ces plastiques par les animaux. De nombreuses difficultés minent déjà l'élevage du bétail au Burkina Faso, parmi lesquelles le problème d'alimentation (insuffisance quantitative et qualitative) surtout en saison sèche, ce qui expose plus les animaux à l'ingestion de corps étrangers, notamment des sachets plastiques qui inondent les décharges urbaines et péri-urbaines (Barro, 2000). En effet, la prévalence de l'ingestion de ces sachets plastiques a été estimé à 31,73%, 28,9% et 25,6% respectivement pour les ovins, les bovins et les caprins à l'abattoir de Bobo-Dioulasso au Burkina Faso. La même étude avait souligné que 86% des éleveurs enquêtés avaient déjà eu dans leurs élevages des mortalités liées à l'ingestion de ces sachets plastiques (Barro, 2000). Ainsi le point de vue de ces éleveurs est donc important pour orienter les actions des décideurs visant à une gestion durable de ces déchets plastiques. Une étude récente dans le Nord du Burkina Faso, avait rapporté des prévalences élevées du phénomène d'ingestion du plastique à l'abattoir de Dori. Ces prévalences étaient de 31,5% chez les ovins, 30% chez les bovins et 23% chez les chèvres (Ouédraogo *et al*., 2022). L'impact négatif des sachets plastiques sur la productivité des animaux a été également souligné par ces producteurs de Dori qui vivent principalement de l'élevage des ruminants. Ainsi, pour mieux comprendre leurs perceptions (connaissances, attitudes et pratiques) sur ce fléau d'ingestion du plastique, cette étude a été initiée dans la zone urbaine et péri-urbaine de la commune de Dori, dans la région sahélienne du Burkina Faso.

II. MATERIEL ET METHODES

2.1. Zone d'étude

L'étude sur les perceptions des producteurs a été menée dans les zones urbaine et péri-urbaine de la commune de Dori (Fig. 1). La commune de Dori compte 78 villages et 8 secteurs. Elle est incluse dans la région du Sahel, qui est la région pastorale par excellence du Burkina Faso (Ouédraogo, 2004 ; Kiema *et al*., 2014), où les ménages ruraux tirent 69% de leurs revenus des activités liées à l'élevage (FAO, 2018).

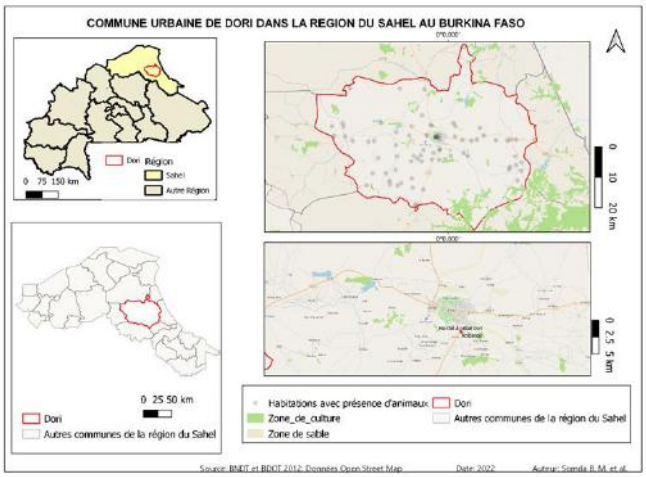

Fig.1: Localisation de la zone d'étude (Ouédraogo et al., 2022)

2.2. Méthode d'étude

L'enquête déroulée de mai à juin 2021, a constitué à une interview individuelle des producteurs. Le choix des producteurs s'est basé sur un certain nombre de critères qui étaient : un cheptel de plus 10 bovins et 10 petits ruminants, un élevage de type extensif ou semi-extensif et la disponibilité de l'éleveur à collaborer. Une liste initiale de quelques producteurs avait été proposée par la Direction régionale des ressources animales et halieutiques (DRRAH) du Sahel et les autres enquêtés ont été obtenus par la méthode « boule de neige » ou par réseautage. Une fiche d'enquête a été élaborée puis renseignée grâce à l'application mobile de collecte KoboToolbox. L'objectif des enquêtes étaient de récolter les perceptions (connaissances, attitudes et pratiques) de ces producteurs par rapport aux impacts liés à l'ingestion des sachets plastiques par les ruminants domestiques.

2.3. Considérations éthiques

Le protocole de l'étude a été validé par la DRRAH du Sahel. Tous les participants ont été informés des objectifs de l'étude dans leurs langues locales, au besoin l'appui d'un guide a été demandé. De plus, un consentement écrit a été obtenu pour les enquêtés impliqués dans l'étude. L'anonymat a été gardé sur l'identité de l'enquêté.

2.4. Analyse des données

Les données de l'enquête ont été collectées grâce à l'application mobile de collecte KoboToolbox puis traitées avec le tableur Excel 2016. Par ailleurs, le logiciel R.4.2.2 (R core Team, 2022) a permis de réaliser des tests de khi-2

sur des données de l'enquête pour mesurer des liaisons entre des variables mesurées. Le seuil de significativité a été fixé à 5%.

III. RESULTATS

3.1. Caractéristiques socio-économiques des producteurs

Les investigations sur les perceptions liées à l'ingestion des sachets plastiques, ont porté sur 60 producteurs composés de 95% (57) d'hommes et 5% (3) de femmes. La majorité des enquêtés était de l'ethnie Peulh (93%), suivie des Mossis (5%) puis des Gourmantché (2%). L'âge des enquêtés était comprise entre 20 et 80 ans avec une moyenne de 53 ± 14 ans. L'élevage était l'activité la plus pratiquée et occupait principalement 82% des personnes, suivie de 13% pour l'agriculture, 3% pour le commerce et de 2% pour activités minoritaires (orpaillage, enseignement coranique, activité de berger, …). La situation matrimoniale des ménages était composée comme suit : 67% (40) de mariés monogames, 30% (18) de mariés polygames et de 3% (2) de célibataires. Les ménages avaient une taille moyenne de 6 ± 4 personnes. Les détails sur ces caractéristiques socio-économiques des producteurs sont résumés dans le tableau I.

Tableau I: Caractéristiques socio-économiques des producteurs

Variables	Modalités	Proportions (effectifs)
Sexe	Hommes	95% (57)
	Femmes	5% (3)
Ethnie	Peulh	93% (56)
	Mossis	5% (3)
	Gourmantché	2% (1)
Principale activité	Elevage	82% (49)
	Agriculture	13% (8)
	Commerce	3% (2)
	Autres	2% (1)
Situation matrimoniale	Marié monogame	67% (40)
	Marié polygame	30% (18)
	Célibataire	3% (2)

3.2. Caractérisation de l'élevage chez les enquêtés

3.2.1. Système d'élevage

Les élevages rencontrés dans la zone urbaine et péri-urbaine de Dori sont exclusivement de type extensif. Les types d'élevages extensifs se répartissent en deux principaux systèmes : transhumance et agropastoralisme (Fig. 2). Le système transhumant est le plus répandu car concernait 83% (50) des producteurs (p < 0,001).

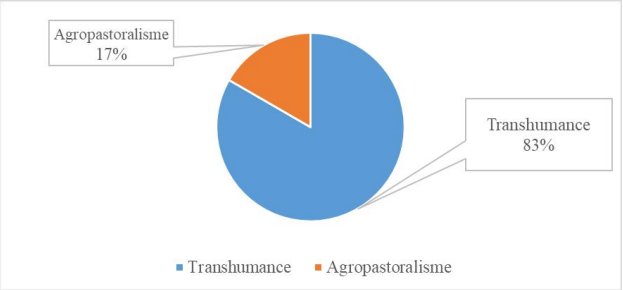

Fig.2 : Systèmes d'élevage pratiqué par les producteurs

3.2.2. Diversité du cheptel des producteurs

Le cheptel des producteurs était constitué de bovins, caprins, ovins, volaille et asins. Dans ce cheptel, l'élevage des caprins était dominant (37%), suivi des ovins (24%), des bovins (22%), de la volaille (15%), et enfin celui des asins (2%). Il ressort que l'élevage des petits ruminants (ovins et caprins) était le plus pratiqué (p = 0,003) et les raisons sont économiques et culturelles.

3.2.3. Mode d'alimentation

L'alimentation des espèces animales élevées était plus composée de pâturage naturel (77%), suivie de résidus de culture (17%) et de sous-produit agro-alimentaires (SPAI) (6%) (p < 0,001 ; Fig. 3).

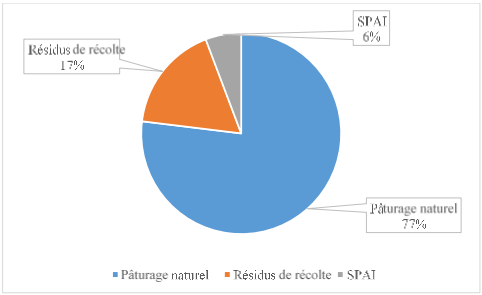

Fig.3 : Alimentation des animaux d'élevage

3.3. Connaissances du phénomène d'ingestion des sachets plastiques par les producteurs

3.3.1. Signes cliniques liés à l'ingestion des sachets plastiques

Selon les producteurs, les signes cliniques liés à l'ingestion de sachets plastiques sont les amaigrissements (43%), les ballonnements persistants (31%) accompagné souvent d'un durcissement de l'abdomen et de la diarrhée (13%), de l'anorexie (12%) et d'un écoulement nasal (1%). Ces symptômes sont représentés dans la figure 4.

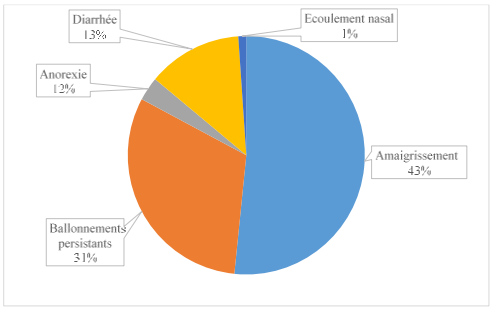

Fig.4: Symptômes liés à l'ingestion des sachets plastiques

3.3.2. Mortalité liée à l'ingestion des sachets plastiques

La mortalité liée à l'ingestion des sachets plastiques dans les élevages touche 71,66% (43) des producteurs. Les résultats de l'enquête ont révélé que cette mortalité touche plus les caprins avec 55% (33), 25% (15) des ovins et 20% (12) des bovins ($p < 0,001$).

3.3.3. Impacts négatifs sur la commercialisation des animaux

Les producteurs élèvent pour avoir de l'argent mais compte tenu du péril plastique, ces producteurs subissent beaucoup de pertes. En effet, avec le phénomène d'ingestion de sachets plastique, sur les 60 producteurs enquêtés, 55% (33) des producteurs estimaient ne pas pouvoir engranger des revenus annuels de plus de 60 000 F CFA à cause de ce fléau (Tableau II).

Tableau II: Revenus annuels des producteurs liés à l'ingestion de sachets plastiques

Revenus annuels (F CFA)	Proportions (effectifs)
0-60 000	55% (33)
60 000-500 000	38% (23)
500 000-1 000 000	7% (4)

3.4. Attitudes et pratiques des producteurs face à l'ingestion des sachets plastiques

Pour confirmer la présence des sachets plastiques chez un animal ayant des ballonnements, certains producteurs, emploient des méthodes empiriques telles que l'utilisation du sucre. En effet, pour un bovin de 1 UBT (Unité de Bétail Tropical), les éleveurs utilisent 1 kg de sucre dilué dans 2 litres d'eau, cela provoquerait la diarrhée chez l'animal. De plus, d'autres éleveurs utilisent du vinaigre ou du citron dilué dans de l'eau pour provoquer la diarrhée chez l'animal. Si après cette diarrhée le ballonnement persiste, cela suppose que c'est un cas d'ingestion de plastiques et l'animal est soit vendu ou abattu.

3.5. Solutions proposées par les producteurs au fléau de pollution liée au plastique

Les solutions envisagées par les producteurs pour lutter contre la pollution par les sachets plastiques dans l'environnement sont diverses. Parmi ces solutions, la sensibilisation de la population sur la gestion des déchets plastiques était la plus proposée avec 51% de citations, suivie du recyclage des sachets (37%), de l'utilisation des sachets biodégradables (8%) et aussi l'interdiction de la vente, de la fabrication et de l'importation des sachets plastiques non biodégradables au Burkina Faso avec 4% de citations (Fig. 5).

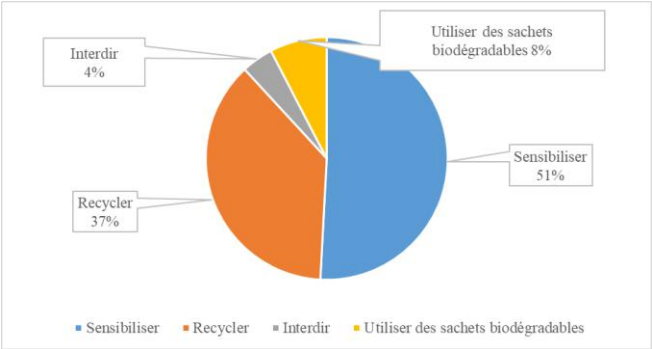

Fig.5: Solutions proposées pour lutter contre la pollution liée au plastique

IV. DISCUSSION

À l'instar d'autres zones agro-écologiques du Sud du sahel, le système extensif caractérise surtout l'élevage des ruminants et la pratique traditionnelle d'alimentation de ces animaux sur des parcours naturels est un moyen de composer la précarité des ressources agro-pastorales. Cependant, le pâturage naturel est de plus en plus bouleversée par le changement climatique, la pression de l'extension des terres agricoles et de l'urbanisation croissante, et la pollution par les décharges de déchets dont le plastique. L'ingestion des sachets plastiques par les ruminants domestiques a un impact négatif pour les acteurs de la filière de l'élevage, alors qu'elle est classée quatrième dans la contribution au Produit intérieur brut (PIB) du Burkina Faso avec 9,9% après l'agriculture, les mines et le commerce (INSD, 2019). Pourvoyeur d'emplois, le sous-secteur de l'élevage contribue également à la sécurité alimentaire et nutritionnelle des

ménages par un apport en produits de hautes valeurs nutritives tels que la viande, le lait, les œufs, etc. (MRA, 2010). Aussi, il permet de stabiliser les populations rurales et d'éviter les migrations à la recherche d'emplois et de revenus (FAO, 2018).

Les élevages rencontrés dans la zone urbaine et péri-urbaine de Dori sont exclusivement de type extensif dominés par le système transhumant à 83%. L'enquête révèle également que le mode d'alimentation des espèces élevées est dominé par le pâturage naturel (77%). La pratique de l'élevage transhumant rencontrée dans la zone pourrait s'expliquer par la prédominance dans la zone d'une tradition pastorale bien développée. De plus en plus, la transhumance est citée comme un moyen efficace d´adaptation aux changements climatiques et de gestion durable des ressources naturelles (FAO, 2012). Cependant, ces pâturages naturels sont de plus en plus pollués par des sachets plastiques. Ainsi, les animaux sur les pâturages ingèrent ces sachets plastiques pour combler les divers déficits nutritionnels. Dans les conditions d'élevage locales, les facteurs prédisposant les animaux à l'ingestion des déchets plastiques sont : la divagation, les carences alimentaires (déficit en calcium et phosphore et en autres micornutriments) liées à la rareté du pâturage associée à sa faible qualité nutritionnelle, l'absence d'un supplémentation dans l'alimentation des animaux, etc. (Vijaya Bhaskara Reddy et Sasikala, 2012 ; Ngoshe, 2012). Les sachets plastiques une fois ingérés demeurent dans le tube digestif et occupent un volume important empêchant l'animal d'ingérer en quantité suffisante les aliments, d'où les pertes de poids importants constatées. En effet, l'encombrement de la cavité gastrique qui peut atteindre 36% du volume ruminal provoque une restriction du volume disponible aux aliments à ingérer. Ce manque à gagner alimentaire chronique plonge l'animal dans un état carentiel avec un amaigrissement progressif aboutissant à court ou long terme à une cachexie et à une dépravation du goût (pica) (Seibou, 1996). De plus, ces sachets plastiques ingérés par les animaux peuvent renfermer des métaux lourds toxiques (cadmium, mercure, etc.) ou peuvent contenir des parasites ou être liés à des corps étrangers (file de fer, aiguille, cuir, papier, morceaux de tissus, cheveux, des clous, etc.) pouvant causer des dommages aux animaux altérant de façon aiguë ou chronique leur état de santé. Ainsi, les morbidités associées aux pertes de poids sont responsables de la baisse des performances zootechniques des animaux qui deviennent des non-valeurs économiques ou meurent tout simplement (Seibou, 1996).

Les symptômes d'ingestion des sachets plastiques par les animaux notifiés par les producteurs enquêtés, montrent que le fléau semble être bien connu par ces derniers. Ces signes cliniques recensés par ordre d'importance étaient l'amaigrissement (43%), les ballonnements persistants (31%) accompagné souvent d'un durcissement de l'abdomen et de la diarrhée (13%), de l'anorexie (12%) et d'un écoulement nasal (1%). Ces symptômes contribuent à altérer davantage l'état de santé de ces ruminants. Des études montrent que les signes cliniques survenant chez les animaux suite à l'ingestion des sachets plastiques varient en fonction de la quantité de plastiques accumulée dans le tube digestif et de la durée du plastique depuis son ingestion dans le tube digestif (Priyanka et Dey 2018). Par ailleurs, dans la zone d'étude, nombreuses pathologies des ruminant renvoient à des symptômes confondants : la trypanosomose animale africaine (Holmes, 2013), les parasitoses internes (Gunn et Irvine, 2003), etc. Ainsi, comme les animaux sont très peu suivis dans les conditions d'élevage extensif, et les méthodes de diagnostic utilisées par les éleveurs sont empiriques et basées également sur des suspicions, la mort des animaux affectés s'en suit généralement. Le diagnostic spécifique d'une ingestion des sachets plastiques chez les animaux constitue donc un défi réel pour les éleveurs et les techniciens du sous-secteur de l'élevage.

Finalement, le phénomène de l'ingestion des sachets plastiques par les animaux est perçu par la plupart des éleveurs comme une des principales causes à l'origine des mortalités enregistrées dans leurs élevages. L'enquête terrain a aussi révélé que la mortalité liée à l'ingestion du plastique est plus élevée chez les caprins, suivis des ovins et des bovins. Ces résultats sont en contradiction avec les résultats de l'abattoir sur les quantités de sachets ingérés qui placent les bovins en tête suivis des ovins et enfin des caprins (Ouédraogo *et al.*, 2022). Cette contradiction pourrait s'expliquer par le fait qu'à l'abattoir, l'abattage des animaux ne sont pas généralement lié à l'ingestion de sachets plastiques. Des résultats similaires à la présente étude avaient été rapportés par Barro (2000), où 86% des éleveurs enquêtés avaient déjà eu dans leurs élevages des cas de morts d'animaux liés au fléau d'ingestion du plastique. Outre, les symptômes observables notifiés, conduisant à des mortalités en question, une baisse de la production laitière et une baisse de la fécondité ont été également soulignées (Sheferaw *et al*., 2014 ; Boerjan, *et al*., 2016). Les causes du phénomène de l'ingestion des sachets plastiques par les animaux semblent être externes aux systèmes d'exploitation des élevages dans la zone d'étude, eu égard des pistes de solutions que ces producteurs ont proposé : la sensibilisation de la population sur la gestion des déchets plastiques ; le recyclage des sachets ; l'utilisation des sachets biodégradables ; l'interdiction de la vente, de la fabrication et de l'importation des sachets plastiques non biodégradables. Otsyina *et al.* (2017) et Fasil (2016)

montrent en revanche qu'une gestion efficace du phénomène dans les élevages passe non seulement par un système de gestion efficace des déchets, mais également par des pratiques standards de conduite des animaux. De plus, l'OCDE évalue deux scénarios avec des mesures renforcées pour venir à bout de la pollution du plastique. Le premier scénario «d'action régionale» prévoit des engagements différenciés par pays, et le second «d'ambition mondiale», envisage un ensemble de mesures très rigoureuses destinées à réduire les rejets mondiaux de plastiques à un niveau proche de zéro à l'horizon 2060 (OCDE, 2022).

V. CONCLUSION

Les éleveurs de la commune de Dori, dans la Région du Sahel sont confrontés à une insuffisance quantitative et qualitative d'aliments pour leurs animaux conduisant ces derniers à ingérer des sachets plastiques sur leurs parcours. Les perceptions des producteurs montrent qu'ils ont une connaissance du phénomène d'ingestion des sachets plastiques : les méthodes traditionnelles pour détecter la présence des sachets plastiques, les pertes économiques et les signes cliniques.

Pour remédier à l'impact de l'ingestion des sachets plastiques chez les ruminants domestiques, des actions coordonnées sont nécessaires dans l'environnement de vie des animaux, notamment avec l'appui des techniciens de l'environnement et de la santé publique, des autorités municipales et communales, etc. A l'issu de cette étude des recommandons suivantes peuvent être faites :

- l'utilisation par la population de sacs réutilisables en tissu, jute et autres fibres naturelles ;

- la vulgarisation de pratiques standards de conduite des animaux incluant une alimentation adéquate avec des suppléments minéraux, la mise en place des banques de fourrages, la création des zones dédiées au pâturage avec des adductions d'eau, etc.

REMERCIEMENTS

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Cloning of phytase gene from *Aspergillus niger* 563 and its expression in *E.coli* system

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Abstract*— *A phyA was cloned from Aspergillus niger by reverse transcription polymerase chain reaction. The amplified 1404 bp fragment was cloned in a T/A cloning vector and confirmed by sequencing. The isolated phytase gene showed 99.0 % sequence identity at nucleotide and protein level with Aspergillus niger CBS 513.88 phytase. The amino acid sequence from the phyA cDNA contained the consensus motifs, RHGXRXP and HD which are conserved among histidine acid phosphatases. The phytase cDNA was subcloned in pET28a(+) expression vector and expressed in E. coli. The expression of the gene was confirmed through SDS-PAGE analysis. A 52 kDa protein as per the calculated molecular mass of the translational product of phytase gene was observed in crude lysate of E. coli culture induced with IPTG. The protein was purified using nickel based His-bind resin column and checked on SDS-PAGE. The purified recombinant enzyme showed a single band of 52 kDa protein. The phytase activity of pET-phyA IPTG induced E. coli culture and purified phytase was 383.5 U/ml and 826.33 U/ml, respectively.

Keywords*— *Aspergillus niger, phytase, cloning, expression, E. coli

I. INTRODUCTION

Phosphorus is one of the most limiting nutrients for animals because most of the phosphorus in the plant seeds including the feeding plants is in the form of phytic acid (De Boland *et al*., 1975), most of which cannot be digested by monogastric animals and acts as an antinutritional factor hindering the uptake of a range of minerals. Furthermore, high phytic acid content in animal manure by excretion results in elevated level phosphorus level in soil and water and accompanying environmental concerns (Lambrechts *et al*., 1992). Phytate also chelates trace elements of iron and zinc between phosphate groups within a single phytate molecule or between two phytate molecules. The enzyme phytase is able to release the bioavailable phosphorus from phytic acid, consequently improving the phosphorus bioavailability and the uptake of minerals. On the other hand, the content of phytase in plant itself is too limited to release sufficient inorganic phosphorus (Brinch-Pederson *et al*., 2002).

Phytases are a special class of phosphatases that catalyze the sequential hydrolysis of myo-inositol-(1,2,3,4,5,6)-hexakisphosphate or phytic acid (Ins P6) to less phosphorylated myo-inositol derivatives and inorganic phosphate (Haros *et al*., 2007). Phytase is the only known enzyme that can initiate the phosphate hydrolysis at carbon 1, 3 or 6 in the inositol ring of phytate. The removal of phosphate group by phytase results in releasing of calcium, iron, zinc, and other metals. Phytate degrading activity has been detected in plants, microorganisms, and in some animal tissues and phytases from several plant and microbial species (Hill *et al*., 2007) have been purified and characterized. In plants, phytase activity is found in many plant seeds (Laboure *et al*., 1993). Hence, although currently phytases are used mainly as animal feed additives in diets of monogastric animals, there is a great potential for the use of this class of enzymes in processing and manufacturing of food for human consumption (Jorquera *et al*., 2008).

Phytase activity has been found most frequently in fungi, such as *Aspergillus ficuum* (Gibson, 1987), and *Aspergillus*

niger (Han *et al*., 2018). Phytase is also produced by gram-positive bacteria, such as *Bacillus* (Farhat-Khemakhen *et al*., 2012 and Saadi *et al*., 2021), and gram negative bacteria, like *Aerobacter aerogenes* (Greaves *et al*., 1967), *Pseudomonas* sp. (Singh *et al*., 2017), *Escherichia coli* (Greiner *et al*., 1993), and *Klebsiella* (Jareonkitmongkol *et al*., 1997). Generally, phytases from gram-negative bacteria are intracellular proteins, while phytases from gram-positive bacteria and fungi are extracellular enzymes (Kim *et al*., 1998; Choi *et al*., 2001). In this study, we cloned and sequenced the phytase gene of *Aspergillus niger* and recombinantly expressed the phytase in *E.coli*.

II. MATERIALS AND METHODS

Chemicals

Sodium phytate, Isopropyl thiogalactoside (IPTG), deoxynucleoside triphosphates (dNTPs) and β-mercaptoethanol were purchased from Sigma Aldrich Chemical Company, U.S.A. All the other chemicals used were of analytical grade manufactured in India.

Strains, plasmids and chemicals

A. niger 563 obtained from National Chemical Laboratory (NCL), Pune was used to isolate a phytase gene. *E.coli* DH5α and Bl21 (DE3) were used as hosts for genetic manipulation and expression, respectively. The vector pTZ52R/T (MBI Fermentas) was used for TA cloning and nucleotide sequencing, and pET28a(+) (Novagen, Madison, WI) was used for expression of phytase in *E.coli*. *E.coli* strains were grown at 37°C in Luria-Bertani (LB) medium.

Total RNA isolation

The hyphae of *Aspergillus niger* was inoculated into PDA medium (20% potato extract and 2% sucrose) and shaken at 100 rpm for 2-3 days at 28°C and mycelia was collected. The total RNA was extracted by method of TRIZOL. One hundred milligram of *Aspergillus niger* mycelial mat was ground with 0.8 ml of trizol reagent followed by the addition of 0.2 ml (1/4th volume) of chloroform. After grinding, sap was transferred to a 1.5 ml microfuge tube, mixed by gentle inversion and kept as such for 3 min. The contents were centrifuged at 12,000 rpm for 20 min and an equal volume of isopropanol was added to the supernatant. After an incubation of 5 min, the mixture was centrifuged at 12,000 rpm for 10 min. Supernatant was discarded and the pellet washed with 70% ethanol. The pellet was resuspended in 100 µl of DEPC treated water (pre-warmed to 65°C) and 13 µl of 2.5 M sodium acetate (pH 5.5). The mixture was incubated at -70°C for 1 h after the addition of 3 volume of absolute alcohol. The contents were centrifuged at 12,000 rpm for 10 min and the pellet washed with 75% ethanol. The pellet was air-dried and dissolved in 20 µl of DEPC treated water. Isolated total RNA was used as template for amplification of the phytase cDNA using RT-PCR.

Cloning of the phytase gene and sequencing

RT-PCR was performed with total RNA isolated from *Aspergillus niger* with a view to obtaining the cDNA corresponding to phytase gene. First strand cDNA was synthesized according to the manufacturer's instructions (RevertAiD™H Minus First Strand cDNA Synthesis Kit # K1631, MBI Fermentas, Germany). PCR reactions were carried out in 20 µl reaction volume containing 2.0 µl of cDNA, 2.0 µl of 10X PCR buffer (10 mM Tris-HCl pH 9.0, 50 mM KCl, 1.5 mM MgCl2), 0.5 µl of 200 mM dNTPs, 0.5 µl of 10 µM of respective forward and reverse primers (PHYF - 5' ATGGGCGTCTCTGCTGTTCTACTTC 3' and PHYR - 5' CTAAGCAAAACACTCCGCCCAATC 3'), 0.5 µl of 1.5 U Taq DNA polymerase (Bangalore Genei Pvt. Ltd., Bangalore, India) and 14.0 µl of sterile double distilled water. Amplification was performed using the temperature profile of the pre-incubation at 94°C for 5 min leading to 35 cycles of melting at 94°C for 1 min, annealing at 54°C for 1 min and synthesis at 72°C for 1 min followed by an extension of 72°C for 10 min.

The PCR product was recovered and purified from a 1.0% agarose gel using a DNA Gel Extraction kit (MBI Fermentas) according to the manufacturer's protocols, then subcloned into pTZ57R/T vector. The resulting plasmid was used for sequence analysis. The methods for E.coli competent cell preparation and transformation were according to the methods of sambrook *et al*. (1989). The recombinants were selected on the LB agar plate containing ampicillin (50 mg/L). The presence of the gene in the recombinant clones was confirmed by sequencing using M13 primers.

Nucleotide and phylogenetic sequence analysis

The nucleotide sequencing of the phytase (*phy*) gene was done by out sourcing at Bangalore Genie (India). Nucleotide and amino acid sequence homology searches were performed on the NCBI database by BLAST search and multiple alignments were done using the CLUSTAL W program. For phylogenetic analysis, gene sequences obtained in this study and phy gene sequences from different *Aspergillus* sp. available in NCBI database were used.

Construction of the expression plasmid

For the expression of mature protein, the entire ORF of the phytase gene without native signal peptide sequence was amplified with the specific primers, ECOF2 (Forward 5' TCCGAATTCCTGGCAGTCCCCGCCTCGAGA 3') and HINR2 (Reverse 5' CGCAAGCTTAGCTAAGCAAAACACTCCGCC 3') with insertion of *Eco*RI and *Hin*dIII sites at the 5' and 3' ends respectively. The PCR product was digested with *Eco*RI and *Hin*dIII and ligated into the respective sites of pET28a(+) expression vector to generate plasmid pET28a(+)-*phyA*.

The pET28a(+)-*phyA* plasmid was transformed into *E. coli* DH5α and subsequently into the expression strain *E. coli* BL21. The transformants cells were grown at 30°C in LB medium containing 50mg/L kanamycin at the mid-exponential phase and their phytase expressions induced by adding isoprophyl β-D-thiogalactopyranoside (IPTG) to the cultures at a final concentration of 1mM.

Induction of phytase in *E. coli*

The *E. coli* strain BL21 harbouring the plasmid pET28a(+)-*phyA* was streaked separately on LB agar plate with kanamycin 50 mg/l and incubated at 37°C for 12-16 h so as to get individual colonies. Single colony was inoculated in 3 ml LB broth containing kanamycin 50 mg/l and grown on a rotary shaker (220 rpm) at 37°C for 16 h. From this, 500 µl of overnight grown culture was inoculated in 50 ml of LB broth and grown at 37°C and 220 rpm till the OD reached 0.3-0.5 at 600 nm. One millilitre of the aliquot was taken in an eppendorf tube and centrifuged at 10,000 rpm for 5 min and the pellet was resuspended in 50 µl of the Laemmli buffer (0.06 M Tris-HCl, pH 6.8, 10% glycerol, 5% β-Mercaptoethanol and 2% SDS) and stored at -20°C for later use as an uninduced culture. The remaining culture was induced by the addition of IPTG (isopropyl-β-D- thiogalactopyranoside) to a final concentration of 1 mM. The culture was allowed to grow at 30°C and the aliquot was collected at 1, 2, 3, 4, 5, 6 and 7 h after induction and the pellet was resuspended in Laemmli buffer. The supernatant were checked for protein expression and purity by Coomassie-stained Sodium dodecyl sulfate (SDS)-polyacrylamide gel (PAGE) 12% electrophoresis.

Purification of recombinant phytase

Recombinant fusion phytase protein was purified using BugBuster® His•Bind Purification Kit (catalogue # 70793-3, Novagen, Germany). For purification, 100 ml of bacterial culture was collected by centrifugation at 10400 rpm for 10 min and protein was extracted with BugBuster™ Reagent. The cells were disrupted by sonication (5 times for 30 seconds). After centrifugation at 11400 rpm for 30 min, the supernatant containing the target protein was purified using His•Bind Resin according to the manufacturer instruction (# TB054, Novagen, Germany).

Phytase assay

Phytase assay was carried out by taking 200 µl of crude sample of phytase into 10 ml test tubes and incubated at 37°C in water bath for 5 min. Two hundred microlitre of 1.25% (w/v) sodium phytate in 200 mM sodium acetate buffer (pH 5.0) was added for enzymatic hydrolysis of phytate, and incubated for 30 min at 37°C. The reaction was terminated by adding 400 µl of 15% trichloroacetic acid. The mixture was centrifuged at 4600 rpm for 10 min and 200 µl of supernatant was added to 1.8 ml of double distilled water. Two millilitre of fresh colour reagent (3 volume of 1 M H_2SO_4 + 1 volume of 2.5% ammonium molybdate + 1 volume of 10% ascorbic acid) was added and mixed well. The mixture was incubated at 50°C for 15 min and left at room temperature for 2-3 min. The absorbance was read at 820 nm, using water as the blank and the serially diluted potassium phosphate solutions as standards. Phytase activity was calculated per ml of culture and expressed as U/ml. One unit of phytase is defined as the amount of enzyme required to release 1 µmol of inorganic phosphate per min from sodium phytate at 37°C.

$$\text{Phytase activity (U/ml)} = \frac{(\mu\text{moles of Phosphate released})\,(df)}{(30)\,(0.200)}$$

df = Dilution factor

30 = Time (in minutes) of assay per the Unit definition

0.200 = Volume (in milliliter) of sample used

III. RESULTS

Cloning and sequence analysis of phytase gene from *Aspergillus niger*

RT-PCR analysis with total RNA isolated from *Aspergillus niger* using phytase gene specific primers showed amplification of a 1404 bp fragment. The 1404 bp band was eluted and ligated with a T-tailed T/A cloning vector. The ligated product was transformed into *E. coli* competent cells. Colony PCR analysis of randomly selected colonies showed the amplification of 1404 bp fragment and restriction digestion of the plasmids isolated from these colonies with the restriction enzymes, *Hin*dIII and *Eco*RI released a fragment of the expected size (Fig.1).

Four clones (CPHY10, CPHY13, CPHY15 and CPHY20) were sequenced using automated DNA sequencer and aligned using CLUSTAL X bioinformatics tool (Fig.2).

Among the clones CPHY13 showed a maximum of 99.0% sequence identity at nucleotide and protein level with *Aspergillus niger* CBS 513.88 phytase (Accession # XM_001401676). The CPHY13 cDNA shared 99.0% sequence identity with the *Aspergillus* species (Accession # DQ192035, AB022700, AY013315) at nucleotide levels and 98.0% sequence similarity with *Aspergillus* species (Accession # AAF25481, AAR08366, ACE79229) at amino acid level. It showed 100% homology at protein level with *Aspergillus awamori* phytase (Accession # ABA29207) and followed by 99.0% with *phyA* - *Aspergillus niger* (Accession # XP_001401713, AAG40885). The cloned fragment contained a single open reading frame of 1404 bp long (from ATG start codon to TAG stop codon), which could potentially encode an approximately 52 kDa protein having 467 amino acids (Fig.3).

The amino acid sequence from the *phyA* cDNA contained the consensus motifs RHGXRXP and HD which are conserved among histidine acid phosphatases. The aligned sequences formed two different clusters. Cluster dendrogram results revealed that the cloned phytase gene from the *Aspergillus niger* formed a separate sub cluster along with the phytase gene sequences of other *Aspergillus* sp. at nucleotide and protein level (Fig.4). The genebank accession number for the *Aspergillus niger phyA* sequence is JQ241266.

Expression of phytase gene in *E. coli*

For the expression of phytase in *E. coli*, the cDNA was cloned in *Eco*RI and *Hin*dIII site of the multiple cloning site of the *E. coli* expression vector pET28a(+). The recombinant colonies were confirmed by colony PCR analysis and restriction digestion (Fig.5). The expression of the phytase gene in *E. coli* was confirmed by SDS-PAGE analysis of crude lysate of *E. coli* BL21 cells harbouring the pET28a(+) vector alone as control and the recombinant pET28a(+) with phytase gene (both uninduced and induced with IPTG). An expected size of protein band (approximately 52 kDa) was observed in the crude lysate of induced culture, which was absent in uninduced culture and in cells with pET28a(+) vector without insert. There was an increase in the amount of induced protein with increase in time. When *E. coli strain* BL21 with pET28a(+)-*phyA* was grown at 37°C, there was no difference in the protein banding pattern of total cell extracts before and after induction with IPTG. In contrast, when the cells were grown at 30°C, an intense 52 kDa band was visible specifically in the extract of induced cells containing the recombinant plasmid (Fig.6). Phytase was purified from the 100 ml culture after 6 h induction with 50 mM IPTG using nickel based His bind resin column according to the recommendation of the manufacturer (BugBuster® His•Bind Purification Kit, Novagen, Germany). On SDS-PAGE, the purified recombinant enzyme showed a single band of 52 kDa. The phytase activity was calculated as 826.33 U/ml for purified phytase and 383.5 U/ml for pET-*phyA* IPTG induced culture.

IV. DISCUSSION

In this study, a phytase gene (*phyA*) was isolated from the cDNA of *A. niger*. This gene contains a single open reading frame of 1404 bp long (from ATG start codon to TAG stop codon), which encodes an approximately 52 kDa protein having 467 amino acids. The phytase from *A. niger phyA* is well characterised by several earlier workers. It is encoded by a 1.4 kb DNA fragment and has a molecular mass of 80 kDa, with 10 *N*-glycosylation sites (Han and Lei, 1999). Average molecular masses of bacterial phytases are smaller than those of fungal phytases (40–55 vs. 80–120 kDa), mainly due to glycosylation differences (Choi *et al.*, 2001; Golovan *et al.*, 2000).

From the sequence analysis it was confirmed that the amino acid sequence from the *phyA* cDNA contained the consensus motifs RHGXRXP and HD which are conserved among histidine acid phosphatases. The clone CPHY13 showed a maximum of 99.0% sequence identity at nucleotide and protein level with *Aspergillus niger* CBS 513.88 phytase (Accession # XM_001401676). These motifs play an important role in the phosphorylation (Kostrewa *et al*., 1997 and Oh *et al*., 2001). A highly conserved sequence motif RHGXRXP (Ullah *et al*., 1991), involved in the catabolic reactions, is found at the active sites of phytase. Furthermore, *phyA* contains a remote C-terminal His-Asp motif (HD motif) that is also likely to take part in the catalysis. Together, it is therefore suggested that the *phyA* belongs to a member of the phytase subfamily of histidine acid phosphatases (Mitchell *et al*., 1997). The conserved sequence RHGXRXP in the substrate-binding site interacts with the phosphate groups in the substrate to form a complex of enzyme-substrate. The HD elements in the catalyzation domain further function to release the phosphate group from the substrate (Loewus and Murthy, 2000; Mullaney *et al*., 2000).

Due to the enormous potential for application of phytase in the animal feed industry, several researchers have attempted to produce this enzyme cost-effectively. *A. niger phyA* phytase has been cloned and over expressed in several microbial hosts, including *S. cerevisiae* (Han *et al*., 1999), *P. pastoris* (Han and Lei, 1999), *A. niger* (Van Dijck, 1999) and *E. coli* (Singh *et al*., 2018). The pET prokaryotic expression system is one of the most effective expression systems, possesses high performance and specific

interaction between bacteriophage T7 promoter and T7 RNA polymerase to increase the expression efficacy of exogenous gene in bacteria. In this study, the recombinant pET-*phyA* construct expressed the phytase enzyme efficiently in the host *E. coli* cells. The expressed protein was purified by nickel based column affinity chromatograph conveniently because of the six histidines tag fused to the *E. coli* protein.

For the expression in *E. coli*, phytase cDNA was cloned in pET vector devoid of N-terminal signal peptide. As *E. coli* cells are not able to cleave the signal peptide of secreted proteins, the cDNA had to be modified to remove the signal peptide. An expected size of protein (approximately 52 kDa) was observed in the crude lysate of induced culture, which was absent in uninduced culture and in cells with pET28a(+) vector without insert. There was an increase in the amount of induced protein with increase in time. This demonstrated that the recombinant DNA had indeed expressed in *E. coli* cells (BL21 strain). When *E. coli* BL21 pET28a(+)-*phyA* was grown at 37°C, there was no difference in the protein electrophoretic patterns of total cell extracts before and after induction with IPTG. In contrast, when the cells were grown at 30°C, an intense 52 kDa band was visible specifically in the induced extract from the subsequent time interval. This report was supported by Phillippy and Mullaney (1997) who reported maximum activity of 1.5 µmol/mg protein. The phytase activity of pET-*phyA* IPTG induced *E. coli* culture was 383.5 U/ml while it was 826.33 U/ml in purified phytase.

Similar results were observed in the methylotrophic yeast *P. pastoris* by the heterologous expression of *Debaryomyces castellii* CBS 2923 phytase and maximum production level obtained was 476 U/ml (Ragon *et al*., 2008). Chen *et al*. (2004) reported the successful expression of *E. coli appA* gene in *P. pastoris* with the maximum phytase activity after an induction period of 96 h, of 118-204 IU/ml at the flask scale and 1880-4946 IU/ml at high cell-density fermentation. Xiong *et al*. (2005) and Bei *et al*. (2001) also reported 865 U/ml and 165 U/ml of enzymatic activity, respectively with *A. niger* phytase in *P. pastoris*.

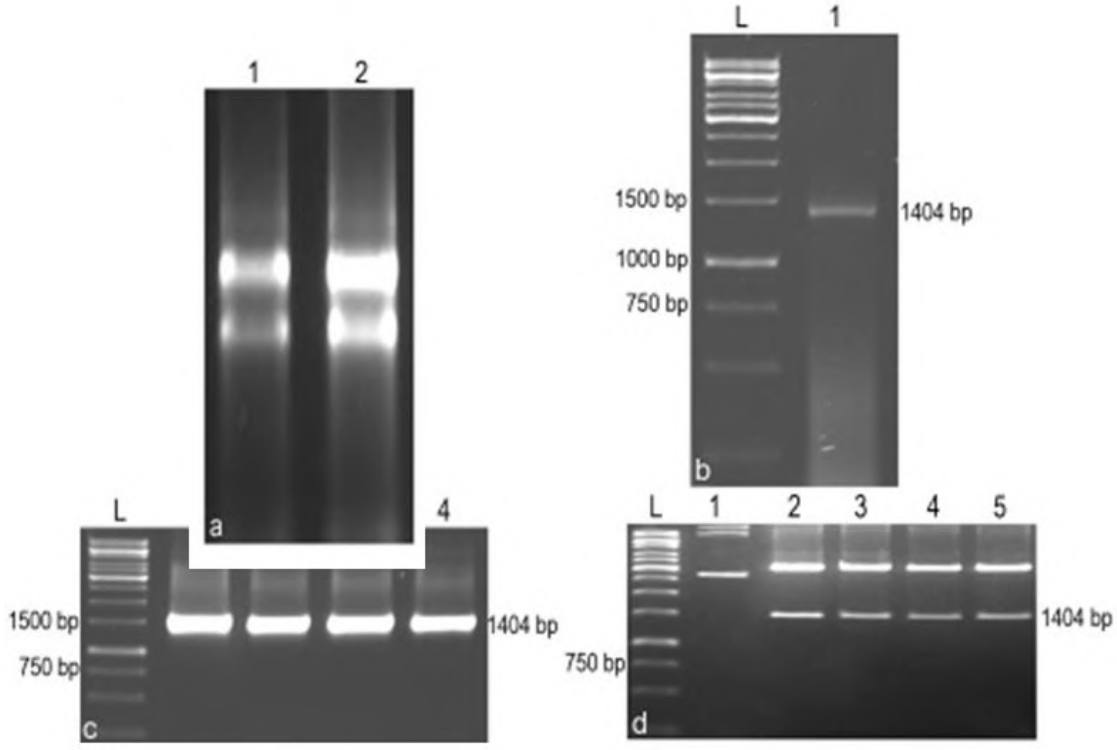

Fig.1. PCR amplification and cloning of phytase gene in T/A cloning vector. a. Total RNA isolated from Aspergillus niger, 1 to 2: Total RNA of Aspergillus niger. b. PCR amplification of phytase gene, L: 1 kbp ladder, 1: Amplification of phytase gene from cDNA of A. niger. c. Colony PCR analysis, L: 1 kbp ladder, 1 to 4: Phytase gene amplfication from selected colonies. d. Restriction analysis, L: 1 kbp ladder, 1: Undigested pTA-phyA plasmid, 2 to 5: Plasmid (from positive clones) digested with HindIII and EcoRI

Fig.2. Multiple sequence alignment of nucleotide sequence of CPHY13 phytase gene from the Aspergillus niger with other related sequences

Consensus motifs of histidine acid phosphatase

. Indicates stop codon

Fig.3. Nucleotide and amino acid sequence of phytase gene (phyA)

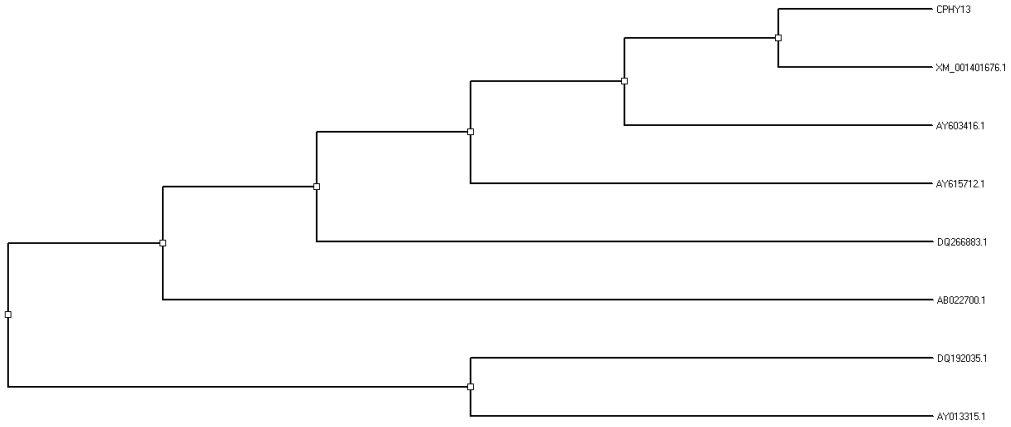

Fig.4.Cluster dendrogram illustrating the phylogenetic relationship based on the multiple sequence alignment of the nucleotide sequences of known phytase gene and the phytase gene from Aspergillus niger.

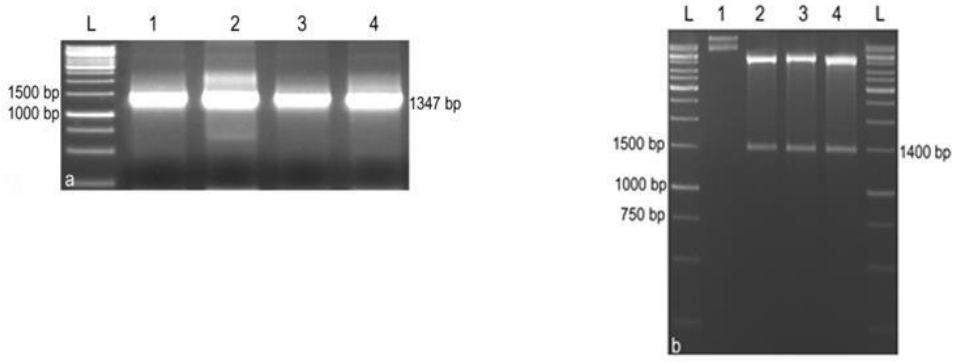

Fig.5. Cloning of phytase gene in E. coli expression vector pET28a(+).
a. Colony PCR analysis, L: 1 kbp ladder, 1 to 4: Amplification of phytase gene from E. coli colonies. b. Restriction analysis, L: 1 kbp ladder, 1: Undigested pET28a(+)-phyA plasmid, 2 to 4: Plasmids (from selected colonies) digested with HindIII and EcoRI

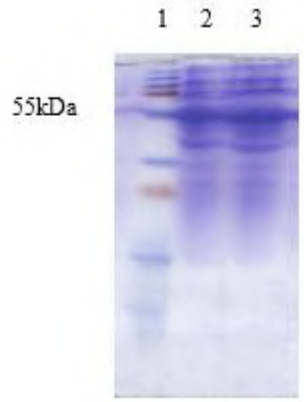

Fig.6. SDS-PAGE analysis of crude lysate of E. coli cells harbouring pET28a(+)-phyA 1: Protein marker, 2&3: Phytase expression after IPTG induction of 6 and 7 h.

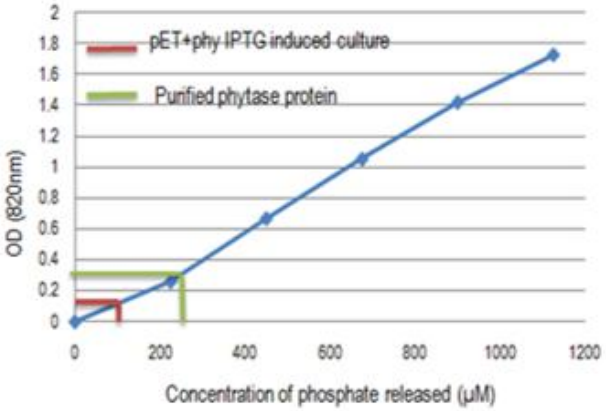

Fig.8. Standard curve for the phosphorus concentration measurement

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Analysis of Nitrogen and Phosphorus Content of Seaweed *Codium* sp. in Super Intensive Shrimp Pond Liquid Waste

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Abstract— *Codium sp. seaweed cultivation trials. Which is different seed weights on the growth media in the form of super intensive shrimp pond liquid waste. The research aims to analyze the ability of Codium sp. absorbing nitrogen and phosphorus from shrimp culture media. The study was conducted for 45 days at the Experimental Pond Installation (ITP) Research and Development Center for Brackish Water Aquaculture (BPPBAP), Punaga Village, Mangarabombang District, Takalar Regency. A plastic box is used by container in this reseach measuring 87 cm x 64 cm with a water level of 40. The study consisted of 4 weight treatments of Codium sp. namely A (50 g), B (100 g), C (50 g) and D (200 g) and each treatment was repeated three times. Data of reseach is analyzed by ANOVA with 95% confidence level and further W-Tuckey test using SPSS version 23 software. The results showed that there was an effect of absorption by seaweed Codium sp. with a seed weight of 200 g resulted in the highest N-total absorption rate of 0.1133±0.01155%, while the highest P-Total absorption rate was at a weight of 100 g with a value of 0.00500±0.002646%.*

Keywords— ***Nitrogen and Phosphorus Content, Liquid Waste, BPPBAP***

I. INTRODUCTION

Pollutant compounds have the ability to lead to a greater decrease in water quality, and waste is one of the hazards to contaminating the aquatic environment. Contaminants in the water will have an impact on the biota there as well as the quantity and quality of fisheries products (Syamsuddin, 2014). One of the major issues with the development of super-intensive technology in Indonesia is the environmental contamination caused by organic waste from super-intensive shrimp ponds that contains nitrogen (N) and phosphate (P) from the usage of a lot of feed (Paena *et al.,* 2020).

The most frequent issue with shrimp farming is the impact of shrimp pond waste on the environment (Buir *et al.,* 2012). The high quantity of organic waste and nutrients from pond water discharge is one of the factors contributing to the reduction in the environmental quality of pond waters. Remaining feed and excrement dissolve in pond water and are then released into the waters beyond the cultivation area, where they contribute to the high organic and nutrient waste output.

According to Stowell (2000), aquatic plants generally have the ability to neutralize specific elements in waterways, which is particularly helpful for treating wastewater. This demonstrates that aquatic plants' capacity to filter substances dissolved in liquid waste may have application in the liquid waste treatment industry.

Due to its ability to extract macronutrients and metal pollutants from the environment, seaweed is an aquatic plant or fishery product that is increasingly exploited in the bioremediation of polluted waters (Neori *et al.,* 2004). In terms of N uptake, seaweed has been found to outperform bacterial filters. Using seaweed as a filter will reduce the amount of ammonium in the water, whereas using a bacterial filter and recirculating the water will cause nitrate levels to gradually rise (Cahill *et al*., 2010)

Research is needed to find a way to use Codium sp. seaweed as a medium for absorbing N-Total and P-

Total in waters, which would minimize pollution of super-intensive vannamei shrimp pond waste.

II. Research Methodology

Location of The Study

The Experimental Pond Installation (ITP) of the Research and Development Center for Brackish Water Cultivation (BPPBAP), Punaga Village, Mangarabombang District, Takalar Regency, South Sulawesi Province, was the site of this study for 6 (six) weeks.

Preparation of seeds

This study used the seaweed Codium sp., sometimes known as oyster thieves (Figure 1). To prevent stress on the seaweed seeds, the seeds are first cleared of any clinging dirt before being acclimated in a basin of filtered seawater. Following that, the seedlings were placed in plastic boxes and preserved after being weighed at various beginning weights (50 g, 100 g, 150 g, and 200 g).

Fig.1. Codium sp. used in research

Preservation of Seaweed

Codium sp. is chosen for seed planting and weighed with an electric balance. The seeds were attached with ropes to coral fragments that were 5 cm and 4 cm thick and that served as the growing medium for super-intensive shrimp waste water. A particularly designed off-bottom approach is used to plant seedlings in culture containers in the shape of plastic boxes (Figure 2).

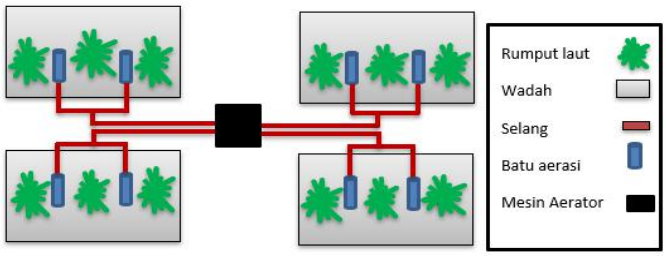

Fig.2. Seaweed cultivation construction

Once a week, media water changes are performed by first sucking out 80% of the water in the container using a hose. Every week, the codium that has been placed in the container is checked to see how it is developing.

Research and treatment planning

Completely randomized design (CRD) was employed in this study, and the following treatments were evaluated:

Treatment A: 50g of *Codium* sp

Treatment B: 100g of *Codium* sp

Treatment C: 150g of *Codium* sp

Treatment D: 200g of *Codium* sp

Parameters

Absorption of Nitrogen and Phosphorus

According to Kitadai et al. (2007), the equation that is used to compute the absorption rate of N and P in seaweed is as follows:

$$Pob = (Ct - Co) \times \alpha / t$$

Where:

Pob = is the rate of N and P uptake of seaweed per square meter of culture (mg/m2/day).

Co =is the initial maintenance N and P concentration of seaweed (mg DW/g).

Ct = is the seaweed's N and P content at the conclusion of maintenance (mg DW/g).

A = Dry biomass of seaweed per square meter of cultivation

t = Duration of upkeep (days)

Data Analysis

Using SPSS version 23 software, an ANOVA and W-Tuckey follow-up test were conducted to ascertain the influence of treatment on the observed variables, namely the absorption of Total N and Total P in *Codium* sp.

III. RESULT AND DISCUSSION

The analysis of variance (ANOVA) findings revealed that *Codium* sp's weight treatment had an impact ($P< 0.05$) on the rate of N-total absorption from super-intensive shrimp pond effluent. According to Tukey's test, treatment D with an initial seed weight of 200 g had the maximum absorption rate of N-total *Codium* sp., which was not statistically different from treatment B. (100 g weight). There was no discernible difference between treatment A (50 g weight) and treatments B and C. Treatment A had the lowest rate of total N absorption (0.0433 0.005%). The following table displays the overall N absorption rate.

Table 1. Absorption rate of N-Total Codium sp

Treatment (g)	Absorption rate N-Total (%) ± Stdv
A = 50	0.0433± 0.00577 [a]
B = 100	0.1000±0.03464 [ab]
C = 150	0.0533±0.02517 [a]
D = 200	0.1133±0.01155 [b]

Note: Divergent letters within a single column signify statistically significant variations between treatments at the 5% level ($p < 0.05$).

Treatment D produced the highest N-total Codium sp. absorption rate. The table above demonstrates a decrease in N-Total content in the water as a result of the seaweed *Codium* sp. absorption, including nitrification, nitrogen assimilation, denitrification, and ammonification, can fix nitrogen for use by organisms. However, because the majority of the nitrogen in the water is present as nitrate and nitrite ions, bacteria with the capacity to convert nitrite to nitrate can aid (Patadjai, 2007).

According to Budiyani *et al*. (2012), a decline in nitrate content denotes a reasonably good uptake of nutrients for growth. According to Kushartono *et al*. (2009), nitrate is a component of nitrogen that is crucial for stimulating a plant's growth so that it can expand quickly. Conversely, if there is a deficiency of nitrogen, it will hinder growth since photosynthesis would be interrupted.

While, Budiyani *et al.* (2012) said that the higher the nitrogen concentration, the less fresh the seaweed is and the easier it is to break the thallus, which stunts the growth of the seaweed.

The Tukey test was omitted since the analysis of variance (ANOVA) results indicated that the seedling initial weight treatment had no impact ($P>0.05$) on the rate of absorption of P-total *Codium* sp. (Table 2).

Table 2. Absorption Rate of P-Total Codium sp.

Treatments (g)	Absorption Rate P-Total (%) ± Stdv
A = 50	0.00233± 0.000577[a]
B = 100	0.00500±0.002646 [a]
C = 150	0.00333±0.002517 [a]
D = 200	0.00392±0.003606 [a]
D = 200	0.00392±0.003606 [a]

Note: Divergent letters within a single column signify statistically significant variations between treatments at the 5% level ($p< 0.05$).

The highest P-total Codium sp. absorption rate was found in treatment B, where it was 0.00500 ±0.002646%, followed by treatments D (0.00392 ±0.003606%), C (0.00333± 0.002517%), and A (0.00233± 0.000577%).

According to Yuniarsih *et al.* (2014), seaweed may take up N and P from the water. According to theory, seaweed used phosphate, an important nutrient involved in photosynthesis, to lower the amount of phosphate in the water. This is in line with Dwijdjoseputro's (1994) assertion that phosphate is an essential nutrient for all kinds of plants since it is a macroelement that is crucial for photosynthesis and other metabolic activities including the production of adenosine triphosphate (ATP). Additionally, phosphate can be swiftly absorbed by aquatic plants, lowering the phosphate level in the water.

The nitrogen percentage in offshore cultivation ranges from 0.44 to 4.73%, and the phosphorus value is between 0.06 and 1.07%. It is consistent with the belief that seaweed typically has a network content of macronutrients N and P that is typically produced at levels between 3.5 and 5% N. (Marinho, 2015; Handa, 2013). Additionally, the results of phosphorus values in Bruhn's research (2016) ranged from 0.3-0.9%.

IV. CONCLUSION

According to the study's findings, media D experienced the greatest decrease in N-Total, or 0.1133%, whereas media B experienced the greatest decrease in P-Total, or 0.00500%.

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Application of advanced molecular to select the variety of Bitter gourd (*Momordica charantia* .L) in Can Tho

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Abstract— *A study was conducted to evaluate the genetic variation in bitter ground to using SNP (single-nucleotide polymorphism) markers. Thirty -five primers showing reliable polymorphism were used .This paper mainly applies the molecular directive from the self-absorbed population of F_6 of Cho Moi/Ben Tre. The Polymorphism on two SNP directives, TP1386 and TP 1877 with Bitter gourd on LG1. A wide variation was observed for morphological traits like the number of days to the first male flower anthesis (29.33–33.67), first female flower anthesis (30.5–38.6), fruit length (19.00–22.80 cm), fruit diameter (12.20–19.60 cm), and yield per plant (933.8–1147.9 g).According to the GGT map, it is easier to determine the genetic pattern of hybrids in the population compared to the genome of the parents in the F_6 generation of the Cho Moi/Ben Tre . With 34 SNPs (single-nucleotide polymorphism) molecules directives on LG1, the genetic distance from 0-112. cM. The selected lines carried a superior homogeneity to the parent on the LG1. The result is 7 lines with F_7 with 100% genes for hight yield the same with the father variety (Ben Tre), carrying hight yield. The seven lines selected are: 1(F2-2-1-7-1); 2(F2-8-17-2-2); 5(F2 -5-3-1-5); 7(F2-25-15-8-7); 10(F2-54-4-1-10; 35(F2-10-6-5-35); 36(F2-5-2-7-36). However, after evaluating F7 lines and comparing phenotypes and genotypes, there were only two lines: 2(F2-8-17-2-2); 7(F2-25-15-8-7)good appty for breeding and hight yield . Named line 7(F2-25-15-8-7) was designated HATRI 07KQ . DNA Sequence of HATRI 07KQ were submitted to GenBank .*

Keyword— ***Bitter gourd , genetics and breeing , GGT, SNP (single-nucleotide polymorphism) molecular, hight yield***

I. INTRODUCTION

Bitter gourd (*Momordica charantia* L.; 2*n* = 22) is an economically important vegetable crop belonging to the subtribe Thalidianthinae, tribe Joliffieae, subfamily Cucurbitoideae and family Cucurbitaceae (Jeffrey, 1980; De Wilde and Duyfjes, 2002). In bitter gourds, gynoecism is under the control of a single recessive gene (gy-1) (Ram et al., 2006; Behera et al., 2009; Matsumura et al., 2014), while two pairs of genes were reported by Cui et al. (2018). The flowering traits like days to first pistillate flower appearance, node at first pistillate flower appearance and staminate: pistillate (♂:♀) flower ratio (sex ratio) are directly related to earliness and fruit yield. Production of hybrid seeds in bitter gourd is highly expensive because it is done mainly through hand pollination. Behera et al. (2020) reported that F1 hybrid was derived from the crosses between pure-line of bitter gourd having good specific combiners for yield and its components. Valyaie et al. (2021) reported that heterosis was obtained in seed quality character and yield.

But utilization of a gynoecious line would be more economical and easier method (Behera et al., 2009). Conventional phenotypic selection for high and stable yield requires the evaluation of yield in multiple environments over several seasons; which is very expensive and time consuming (Yuan et al., 2002). Application of molecular indicator combining selection by traditional hybridization method shortens time in breeding (Lang et al 2020).QTL

analysis was performed for six major yield-contributing traits such as fruit length, fruit diameter, fruit weight, fruit flesh thickness, number of fruits per plant and yield per plant. These six quantitative traits were mapped with 19 QTLs (9 QTLs with LOD > 3) using composite interval mapping (CIM). Among 19 QTLs, 12 QTLs derived from 'Pusa Do Mausami' revealed a negative additive effect when its allele increased trait score whereas 7 QTLs derived from 'DBGy-201' revealed a positive additive effect when its allele trait score increased(Rao et al.,2021).The microsatellites i.e.SSR markers are mostly preferred because of their co-dominance, repeatability and easy transferability even though the initial cost of development of these markers is very hig (Powell, et al 1996). However, the number of microsatellite markers available in *Momordica* species is few(' Saxena, S. *et al* 2015). It is established that a greater number of markers are necessary for the development of a genetic map and marker-assisted selection(Tang et al.,2007). It is applied recently as a very reliable tool for marker-assisted selection in accelerating crop improvement program (He et al.,2014). One major QTL *qYD1* and two minor QTLs *qYD15* and *qYD20* explained 23.28% of phenotyping variation for yield per plant. The QTLs identified in the present study will be helpful in marker-assisted selection and molecular breeding in bitter gourd crop improvement.(Rao et al.,2021)

In VietNam , very limited information is available for determining nature of gene effects and inheritance of yield and yield contributing attributes in bitter gourd. For this purpose the present experiment was undertaken to breeding program with component and marker assited selection (MAS)bitter gourd for the development of high yielding variety.

II. MATERIALS AND METHODS

Plant materials

A Cho Moi was crossed with Ben Tre of bitter gourd F_7 population was developed. Ten parents were crossed to develop F1 seeds .Twenty of a single F_1 plant derived from the cross Cho moi/ Ben Tre were developed. The female flowers of these plants were bagged before flowers opened and were hand-pollinated by rubbing matured anthers of the male flowers on receptive stigma of the female flowers early in the morning. The hybridized female flowers were kept bagged until formation of visually conspicuous green ovaries. The F1 plants selfed to develop F_2 population (150), the F_2 population was selfed individually to develop 150:F3 families , plants selfed continue to F_4: $F_5$and F_6 About 50 F_6:7 seeds from each family were sown in a single row with three replications, following recommended agronomic practices.

DNA isolation and molecular marker analysis

DNA extraction. The ninety varieties were grown in pots. Maximum protection was employed to ensure healthy and disease free-growth of seedlings. Leaves were collected 2-3weeks after planting for extraction of DNA.

Standard molecular grade chemicals and general techniques for preparing stock solutions, buffers, reagents and equipment were followed according to Sambrook et al., (1989). Molecular work was conducted at the Genetics and Plant Breeding Department of HATRI , Vietnam

DNA suitable for PCR analysis was prepared using a simplified procedure according to Mc Couch et al., (1988). A piece of young rice leaf (2cm) was collected and placed in labeled 1.5ml centrifuge tube in ice. The leaf was ground using a polished glass rod in a well of a Spot Test Plate (Thomas Scientific) after adding 400µl of extraction buffer .Grinding was done until the buffer turned green, an indication of cell breakage and release of chloroplasts and cell contents. Another 400µl of extraction buffer was added into the well by pipetting. Around 400µl of the lysate was transferred to the original tube of the leaf sample. The lysate was deproteinized using 400µl of chloroform. The aqueous supernatant was transferred to a new 1.5ml tube and DNA precipitated using absolute ethanol. DNA was air- dried and resuspended in 50µl of TE buffer (Lang 2002)

DNA quality checks used 1% agarose by melting 3g agarose in 300ml TAE buffer . The mixture was heated in microwave for 5-6 minutes and then cooled to around 55-60^{0}C. This was then poured on prepared electrophoresis box with combs. Gels were ready and combs removed after about 45 minutes. Seven microliters of DNA sample plus 3µl loading buffer (Tris 1M pH = 8.0, glycerol, EDTA 0.5M pH = 8.0, xylene cyanol 0.2%, bromphenol blue 0.2% and distilled water) was run at 70-80v, 60mA for 45 minutes or until loading buffer dye moved far from the wells. Gel was then taken out and stained with ethidium bromide after which was visualized under UV light.(Lang 2002)

Microsatellite Analysis

The whole microsatellite analysis included PCR assay, polyacrylamide gel electrophoresis, band detection and scoring.

PCR assay. Microsatellite primers were used to survey polymorphism on the samples. These were randomly selected from the 34 microsatellite primer pairs currently available for bitter groud(Rao et al., 2021). The PCR reaction was as follows:

Reactions were overlaid with mineral oil and processed in a Programmable Thermal Controller

programmed for 35 cycles of 1 min at 94^0C, 1 min at 55^0C and 2 min at 72^0C, with a final extension at 75^0C for 5 min. After amplification, 10µl of stop solution was added to the PCR product which was then denatured at 94^0C for 2 min. Eight microliters of each reaction were run on polyacrylamide gel.

***Band detection and scoring*.** Plates were separated using a plastic wedge and removed from the tank. The acrylamide gel was soaked in ethidium bromide staining solution for 15 to 20 minutes. Bands in the ethidium bromide-stained gels were detected and photographed under UV light. Allelic bands were scored as 1 or 0 for presence or absence, respectively. Data were entered directly into an Excel spreadsheet.

Data Analysis

Analysis of variance. The agro-morphological data collected were initially analyzed through analysis of variance to verify genetic variation in the traits measured. The few traits with insignificant genetic variation, based on the F-test, were not considered for further analyses.

Recording of trait data

Fully matured unripe fruits were picked from each F_7 plant over the duration of fruit production. Some fruits were studied in situ and left to ripen for collection of seeds. Qualitative traits including fruit color were recorded visually.

-Hight plant (m): The Hight of the plant was measured in meters from the ground level to the tip of the vine of plants

-Days to first male flowering: The number of days taken from sowing of seed to the opening of first male flower on the plant was recorded as days to first male flowering and number of days taken from sowing of seed to the opening of first female flower on the plant was recorded asdays to first female flowering.

-Days to first female flowering: The number of days taken from sowing of seed to the opening of first female flower on the plant was recorded as days to first female flowering.

-Fruit length (cm) and fruit diameter(cm): The observations regarding fruit length and diameter were measured from five fruits, randomly selected from each treatment, at second, fourth and sixth pickings, respectively. Five randomly selected fruits were taken from the harvested fruits in each replication when

it reached edible maturity. The fruits were cut longitudinally and length was measured with the help of a measuring tape and fruit diameter was measured with digital Vernier calipers.

-Number of fruits per plant: Number of edible fruits was counted at each picking and summed up for all the pickings for aplot. Number of fruits per plant was calculated after dividing total number of fruits in a plot by total number of plants in a plot.

GGT mapping assesses the genetic diversity of hybrid populations

(1) Genotype testing of hybrid populations on LG1 is based on polymorphic molecular markers between parent and parent plants. GGT mapping assesses the genetic diversity of hybrid populations, thereby selecting individuals carrying the desired target gene The GGT method proposed by Tanksley et al. (1998) and, Van Berllo (2008), Milne et al. (2010) built this useful software. GGT 2.0: "graphical genotyping" is a new method developed by the authors of Wageningen University, where alleles express dominant contraction, recessive contraction, and heterozygosity in all hybrids in a population, allowing the selection of individuals to gather the desired genes in the most effective way. GGT mapping method through the following steps: Excel data file: encoding the population gene with A, B being the homozygous genotype of the parent tree; H is a heterozygous genotype; Tumors are unidentified genotypes; (2) Import data into the GGT window: convert Excel data to GGT data; (3) data processing in GGT.

III. 3. RESULT OF DISCUSSION

3.1. Development of Bitter gourd hybrid populations

3.1.1.Diversity of gene sources on parent Bitter gourd varieties from (Cho Moi/ Ben Tre) The selection of peanut varieties using MAS has brought certain successes in recent times such as: shortening the selection time, selecting varieties resistant to adverse conditions, disease-resistant varieties, quality varieties. Therefore, the parent Bitter gourd varieties (Cho Moi and Ben Tre,) were genotype-analyzed to consider carrying hight yield genes, and at the same time, molecular markers of genes related to yield and yield components. Sixty-nine molecular directives were used to assess genetic diversity between parent Bitter gourd varieties, but only 34 for polymorphisms with parents: including 2 molecular TP 1386 and TP 1877 directives marked genes that regulate the hight yield .PCR production detected parent varieties (with gene markers involved 16 marker TP 5296, TP5205,TP5058,TP3064,TP3003,TP2693,TP2480,TP2443 . TP2345. TP2313, TP2199,TP1992, TP1877, TP1459, TP 1386 , TP 1323 on polyacrylamide gel with silver nitrate staining(figure 1)

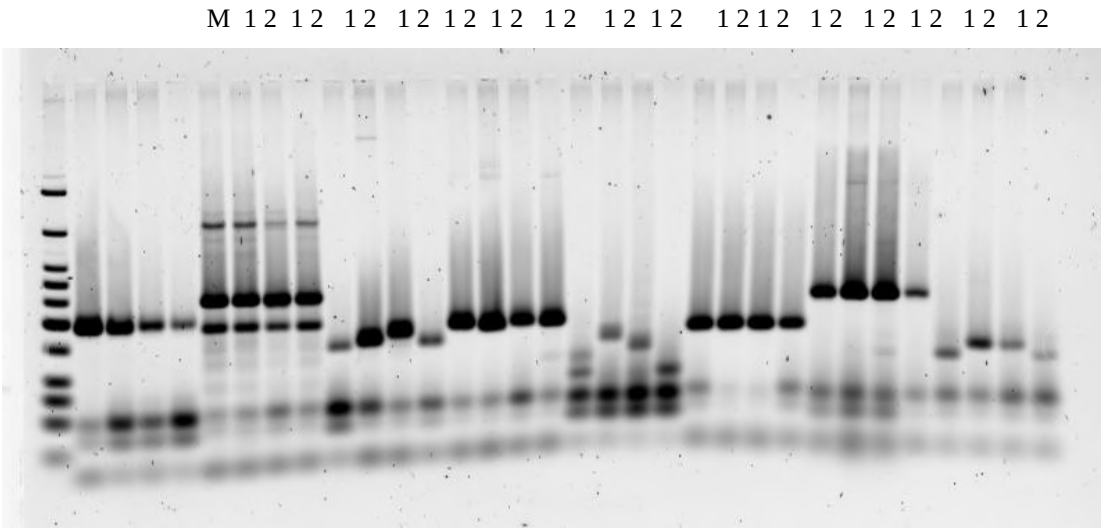

Fig.1: PCR production detected parent varieties (with gene markers involved 16 marker TP 5296, TP5205,TP5058,TP3064,TP3003,TP2693,TP2480,TP2443. TP2345. TP2313, TP2199,TP1992, TP1877, TP1459, TP 1386 , TP 1323 on polyacrylamide gel with silver nitrate staining.

Notes : M. DNA lamda , 1: Cho Moi and 2: Ben Tre.

3.1.2. Development of hybrid populations :The parent seeds were planted at the HATRI Institute's green house and resulted in 45 F_1 plants. Twelve one plants identified as hybrids actually carry both heterozygous alleles from their parents due to to molecular directives. These twelve one F_1 are used to F_2. Of the 150 F_2 Plants, thirty-two were found to carry both parent alleles in heterozygous condition. Generation F_1, F_2, F_3, F_6 were genotyped with markers, and the last four were identified as homozygous for both alleles with large particle sizes (Figure 3, Figure 4,). According to Rao et al. (2021), the nuclear indicator gene on Bitter gourd is controlled by the hight yield localized on LG 1 associated with TP1877 andTP 1459 , and TP1386. Three marker , TP1877 and TP 1459 , and TP1386 are therefore used to test genes associated with hight yield .

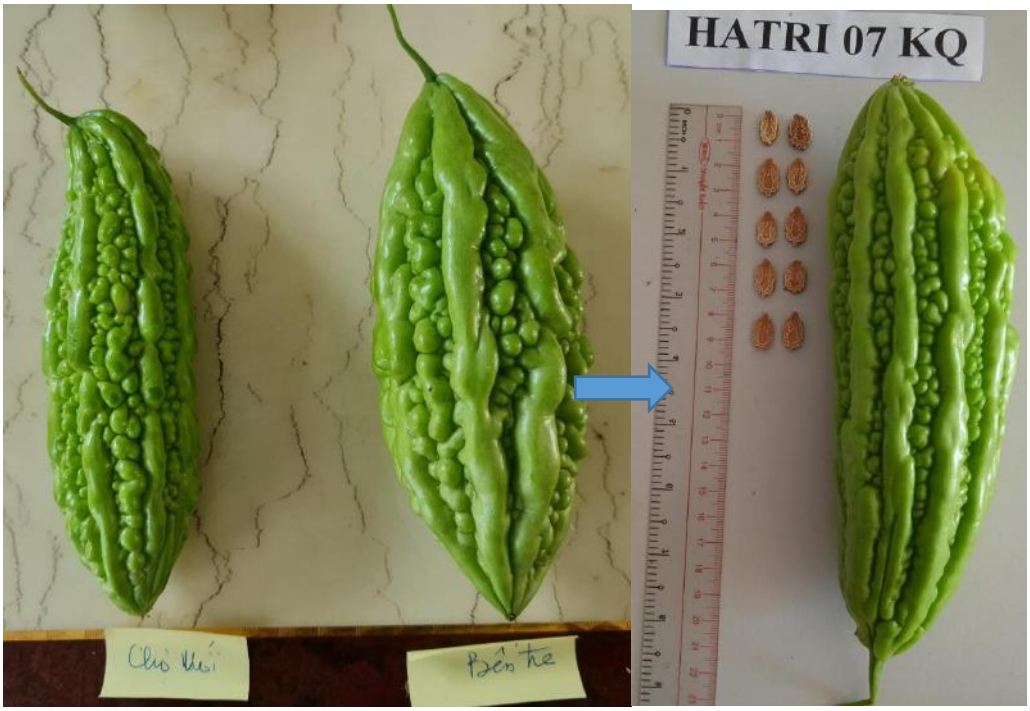

Fig.2: Cho Moi and Ben Tre for parents and F7 generation hybrids: named HATRI 07KQ

3.1.3. Application of molecular marker on F_3 populations

Closely LG1 with marked by molecular marker TP1386. This gene is associated with the particle size group according to (Rao et al. (2021). The TP1386 molecular was used on the F3 population to evaluate and select the high yield of bitter ground. DNA is extracted from a segregating population derived from a cross of Cho Moi/ Ben Tre. Marker TP1386 has a size (300-350bp)detected . In the F3 population with a common parent and the same population size of 50 plants were also compared (Figure 3). The segregation pattern (Figures 3) . The results showed that there were 4 lines the same with Ben Tre (1,29,37 and 50) . and 20 lines the same with size marker Cho Moi (14,15,16,24,25,26,27,28,30,31,32,33,34,35,36,37,38,40,41, 42(300 bp) . Other individuals carry heterozygous genotypes of the same size as their parents(300-350bp).

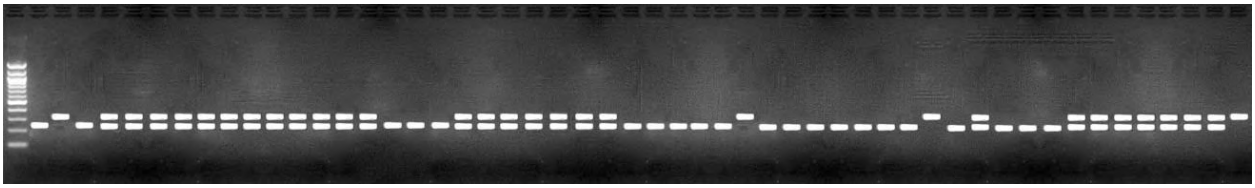

Fig.3: PCR product amplified from DNA extract F_3 population . The primers are TP 1386 with two bands position 300bp (Cho Moi) and 350bp (Ben Tre), on 3% agarose gel.

Note: M: molecure weight marker; P1: Cho Moi , P2: Ben Tre , 1-50 is F3

Similar to the results of the PCR product in Figure 4 with the molecular directive TP 1877 recorded from the population Cho Moi/ Ben Tre give 6 homozygous plants with the allele of the product such as Ben Tre variety.The results of the PCR product show that there are 6 individuals at positions 1,2,5,7 ,10 and 26 of the same size as Ben Tre corresponding to the size of 210bp. There are 17 individuals in position 31,32 ,40,41,42,44,45,46,48,49,50 of the same size as Cho Moi with 250 bp. Other individuals carry heterozygous genotypes of the same size as their parents(210-250bp). Thus, two molecular guidelines (TP 1877) on population show that the F_3generation is still quite strongly dissociated by 26-60% for the two molecular directives above in order.

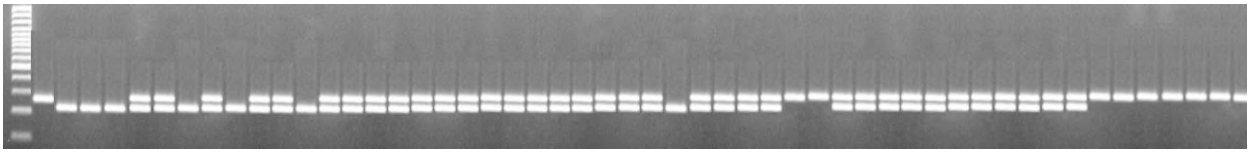

Fig.4: PCR product of the molecular TP 1877 on 50 Lines of gene on LG 1, two bands position 250 bp (Cho Moi) and 210bp (Ben Tre), on 3% agarose gel.

Note: M: is the standard marker; P1: Cho Moi , P2: Ben Tre , 1-50 is F_3

3.3. Selection of populations through GGT mapping

3.3.1. Selection of F_6 individuals of hybrid populations

The F_5 population of the Cho Moi/ Ben Tre hybrid pair gives continued self-absorption and F_6 generation selection. In the F_6 population, 27 lines were selected for genotype assessment through the chromosome LG1 map on each GGT (Graphical genotyping), which is a method that allows the expression of dominant, recessive, heterozygous alleles of a population. The GGT map makes it easier to identify the genetic pattern of hybrids in the population compared to the gene segment compared to the parent. GGT map is built on the Cho Moi/ Ben Tre platform in the F_6 generation. On this map, the gene that regulates particle size traits is marked by 22 molecular indicators on LG1, the migration distance.

The GGT map in Figure 5 shows that 7 individuals have 100% of the gene regions that coincide with the father (Ben Tre), carrying the target gene hight yield . Selected individuals are 1(F2-2-1-7-1); 2(F2-8-17-2-2); 5(F2 -5-3-1-5); 7(F2-25-15-8-7); 10(F2-54-4-1-10); 35(F2-10-6-5-35); 36(F2-5-2-7-36). This noted that on 7 generation lines selected from F_2 to F_7, there was a homogeneity of large and small particle sizes on these lines. Particularly, two individuals 41(F2-7-2-9-41) recorded above accounted for 95.2% of the large content of Ben Tre . This individuals continue to choose the F_8 generation to continues in breeding.

3.3.2.Phenotypic evaluation of the Cho Moi/ Ben Tre :the F_6 population continued lines after evaluation by molecular directive continued planting for F_7 generation dissociation,particle size of selected lines in the field on the

basis of the generation analyzed phenotype. In the generations that continued to selected the F_7generation, the indicators hight plant, days to first male flowering, days to first female flowering, fruit length, fruit diameter and number of fruits per plant were statistically significant. The tallest variety was 2(F2-8-17-2-2) (231.5 cm) and the shortest was 10(F2-54-4-1-10) (165.3 cm). For Days to first male flowering , the longest was of controlled parents trial (14.5-24.5 d) followed Days to first female flowering (19.5-28.8 d). The length(19-22.8 cm) and fruit diameter (12.2-19.6cm) .The yield of all the lines derived Cho Moi/Ben Tre were hight yield to the yield of the standard checks with parents . At Cai Răng , with eight F_7 and two checks from parents were evaluated in three replications . The highest yield was obtained from line 7(F2-25-15-8-7) (1147.9g/plant) next line 2(F2-8-17-2-2) (1145.8g/plant).

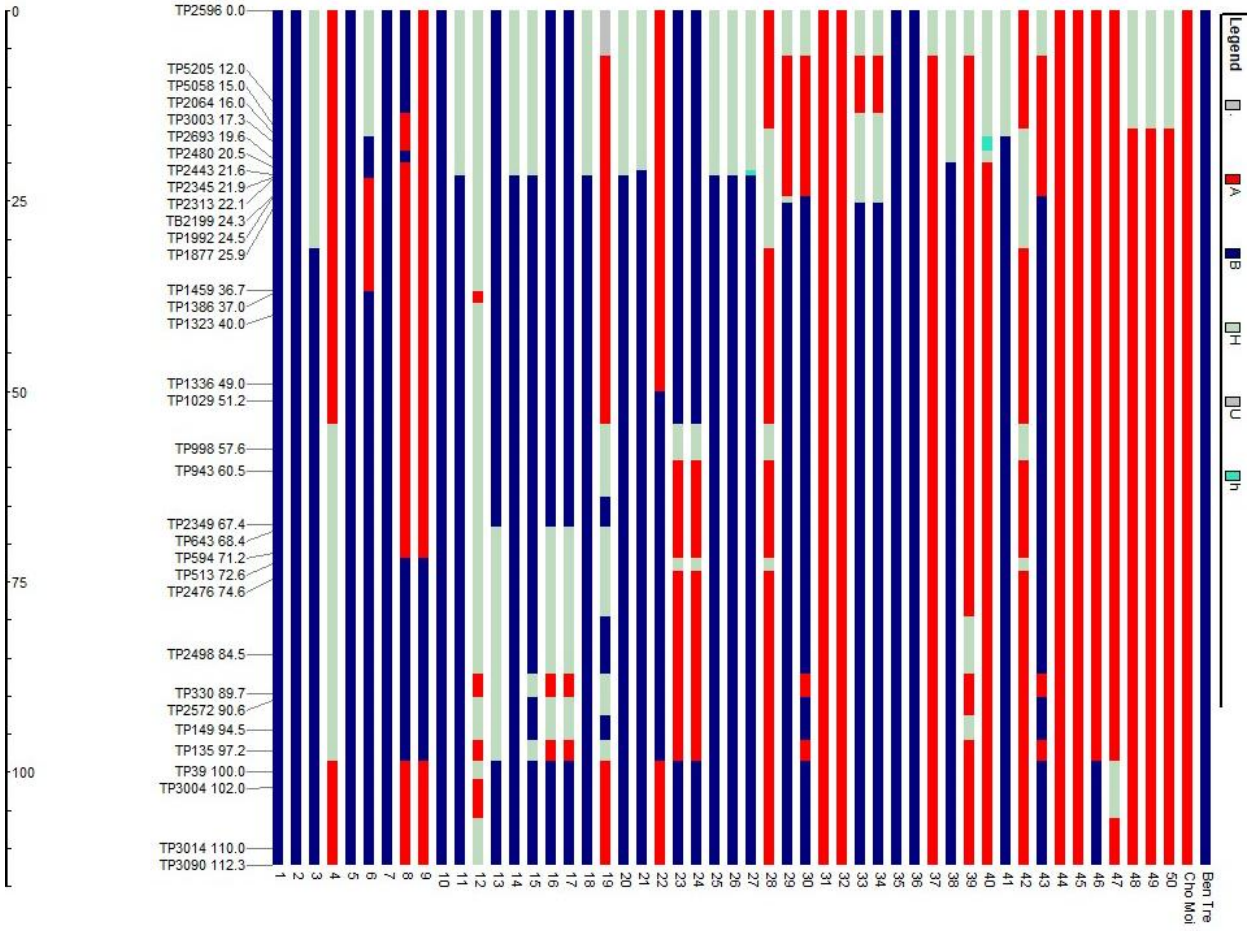

Fig.5: A. Generation F7 genetic diversity in hybrid populations of Cho Moi / Ben Tre on F7 of bitter grounder

Note: blue: genotype according to the parent (Ben Tre), red: genotype according to the parent plant (Cho Moi), gray: heterozygous genotype, greencolor : marking selected individuals, 1-50: individuals of the Cho Moi/ Ben Tre population from F6. Figure 5.B.

Table 1: Yield and component yield on bitter ground at CaiRang (CanTho)

Bitter groud	Hight plant(cm)	Days to first male flowering	Days to first female flowering	Fruit length (cm)	fruit diameter (Cm)	Number of fruits per plant
1(F2-2-1-7-1)	228,8b	21,2a	32,3c	21,1a	16,2c	1140,7b
2(F2-8-17-2-2)	231,5a	29,5a	38,67a	22,8a	15,8d	1145,8a
5(F2 -5-3-1-5)	209,9c	22,9a	32,9c	21,2a	19,8a	1140,5b
7(F2-25-15-8-7)	171,7d	22,2a	30,6c	22,2a	19,7a	1147,9a
10(F2-54-4-1-10)	165,3e	19,9b	35,6b	22,0a	16,5c	1138,4c

35(F2-10-6-5-35)	227,8b	21,1b	35,9b	21,2a	13,5e	937,6d
36(F2-5-2-7-36)	222,2b	22,1b	37,8a	19,1b	12,4f	933,8d
41(F2-7-2-9-41)	221,2b	24,5c	30,5c	19,8b	12,2f	1128,0c
Cho Moi	226,5b	23,1b	38,8a	19,0b	15,4d	910,5d
Ben Tre	201,2c	16,1b	30,8c	20,9a	19,6a	1140,7b
Cv	9,2	1,1	4,9	1,22	1,38	2,62

IV. DISCUSSION

The goal of a plant variety multiplication program is to make a change and select the desired genotype(s) for cultivation or for breeding purposes. Selection of species was based on careful consideration of a number of factors including their economic importance in targeted geographical areas, nutrient density, access to genetic resources, the improvement in the status of the crop globally, and unsolved production constraints and WorldVeg's comparative advantage in solving them versus the private sector (World Vegetable Cente,2019). Bitter ground , which are a highly self-pollinating crop, require special attention in detecting, passing high yields and selecting because these processes require special skills and can be time consuming. Genetic research assists breeders in understanding the mechanism of inheritance and improving the effectiveness of a breeding program. Significant progress has been made in the genetics and plant breeding of peanuts for many years. In recent years, the discovery of polymorphic molecular directives (SNPs) in combination with developed sequencing technologies has led to a significant improvement in fine mapping processes (Rao et al., 2021) .The yield of bitter ground is genetically controlled by polygenic factors. High-resolution mapping of quantitative loci (QTLs) with linked markers can facilitate marker-assisted selection in seed selection for target characteristics. In the current study, with the population of Cho Moi crossed with Ben Tre variety for hight yield , there is an improvement. A graphical representation of molecular marker data can be an important tool in the process of selection and evaluation of plant material. A computer program was developed that enables representation of molecular marker data by simple chromosome drawings in several ways. Commonly used marker file types that contain marker information serve as input for this program, which was named 'GGT' (an acronym of Graphical GenoTypes)(http://www.dpw.wau.nl/pv/pub/ggt/ www.plantbreeding.nl (in prep)2007. Besides representation, GGT can also be used for a diverse range of selections and analyses.Used to build GGT maps based on the 34-loci molecular directive and extending the length of 112 cM. The GGT map in Figure 5 shows that 7 individuals have 100% of the gene regions that with the father (Ben Tre variety), carrying hight yield . Selected individuals are two lines 7(F2-25-15-8-7) (1147.9g/plant) next 2(F2-8-17-2-2) (1145.8g/plant) apply in the future. Named line 7(F2-25-15-8-7) was designated HATRI 07KQ . DNA Sequence of HATRI 07KQ were submitted to GenBank .

This noted that over 4 generation lines selected from $F_3$to F_7 there was a homogeneity of large and medium sizes on these lines. Molecular indicators are marked and developed targeting marker loci associated with varieties for good dissociation and high heterozygous rates are TP 1877 . The hight yield and quality are important for bitter ground selection and production, so a more mechanical understanding of shell development and seed maturation will be conducive to improving these characteristics.

V. CONCLUSION

Selected hybrid individuals must carry the dominant homologous gene on the corresponding chromosome region obtaining 7 lines containing 100% of the gene region that with the father (Ben Tre), carrying the target gene hight yield . A wide variation was observed for morphological traits like the number of days to the first male flower anthesis (29.33–33.67), first female flower anthesis (30.5–38.6), fruit length (19.00–22.80 cm), fruit diameter (12.20–19.60 cm), and yield per plant (933.8–1147.9 g). With 34 SNPs (single-nucleotide polymorphism) molecules directives on LG1, the genetic distance from 0-112. cM. The selected lines carried a superior homogeneity to the parent on the LG1. The result is 7 lines with 100% genes for hight yield the same with the father variety (Ben Tre), carrying hight yield. The seven lines selected are: 1(F2-2-1-7-1); 2(F2-8-17-2-2); 5(F2 -5-3-1-5); 7(F2-25-15-8-7); 10(F2-54-4-1-10; 35(F2-10-6-5-35); 36(F2-5-2-7-36). However, after evaluating F_7 lines and comparing phenotypes and genotypes, there were only two lines: 2(F2-8-17-2-2); 7(F2-25-15-8-7)good appty for breeding and hight yield . Named line 7(F2-25-15-8-7) was designated HATRI 07KQ . DNA Sequence of HATRI 07KQ were submitted to GenBank .

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The potential of Zai pit technology and Integrated soil fertility management to enhance crop productivity in semi-arid regions of Sub-Sahara Africa: A review

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Abstract— *Low and continuously deteriorating soil fertility coupled with frequent droughts and extended mid-season dry spells scenarios brought about by low and unreliable rainfalls have had a significant negative influence on agricultural productivity in most semi-arid regions of the world. The farmers' limited capacity to change their farming practices and adjust to the changing climatic circumstances further exacerbates these effects. Various in-field rainwater collection techniques, including Zai pits, have been promoted in recent years to assist farmers, particularly in dry and semi-arid locations, to harvest, store, and use rainfall for increased crop productivity. Zai pit is a form of dryland farming technique that involves the unitization of holes or troughs aimed at ensuring soil maintenance, soil erosion control and water preservation in agricultural fields. Additionally, combining effective soil fertility management strategies, such as integrated soil fertility management, with rainwater harvesting methods has the potential to further boost crop yields. Integrated soil fertility management involves the combined use of inorganic fertilizers and organic fertilizers such as cattle manure with the aim of improving soil fertility. Zai pit technology and integrated soil fertility management techniques have been utilized as climate smart agricultural approaches to reduce soil moisture stress and improve crop productivity in arid and semi-arid regions. This paper reviews previous research results on crop productivity as influenced by Zai pit technology and integrated soil fertility management techniques.*

Keywords— ***Zai Pit, Integrated Soil Fertility Management, Adoption, Crop productivity***

I. INTRODUCTION

In dry and semiarid regions of the world, insufficient rainfall, soil water stress, and inadequate nutrient availability are the key factors limiting crop productivity (Yazar & Ali, 2016). Insufficient rainfall and poor rainfall distribution have resulted in reduced crop yield and food insecurity in the majority of sub-Saharan Africa's dry regions (Kimaru-Muchai et al., 2020). Additionally, the regular occurrence of extreme weather events such as droughts and dry spells in Africa's rainfed agricultural systems poses a threat to food security (Ayanlade et al., 2018; Grafton et al., 2015). Low rainfall, soil moisture stress, infertile unproductive soils, and increased land degradation have all been linked to low crop productivity in the majority of these areas (Njeru et al., 2015). Majority of farmers in arid areas face drought and prolonged dry spells (Muller, 2014), which promotes food insecurity (Ayanlade et al., 2018).

In these environments, agricultural output is significantly impacted by drought episodes that are frequently linked to

climate variability (Tumushabe, 2018). According to Zougmoré et al. (2014), the arid and semi-arid lands (ASALs) are characterized by low and uneven rainfall during the growing season, crusted, degraded soils that are low in nutrients, and low soil fertility that adversely affects crop output. Climate change, which impact the majority of the sub-Saharan African nations, has made the situation worse in these arid regions (Sakadzo & Kugedera, 2020). According to Muller (2014), more than 13 million people, including 3.75 million Kenyans, were affected by drought in the Horn of Africa region between 2008 and 2010. Additionally, Omenda et al. (2021) argues that African rain-fed agricultural systems will severely be affected by the ongoing climate change and variability. Irrigation often occurs on less than 5% of the total cultivated area in the majority of Sub-Saharan African nations (Peacock et al., 2004). The potential influence of innovations targeted at enhancing farm productivity has been downplayed due to the unpredictability and risk for existing farm level production linked with the fluctuation of rainfall volume and distribution within and between seasons (Biazin et al., 2012).

The United Nations' Globe Water Development Report notes that there has never been a more thirstier world than what we have today (Richard, 2015). The basis for international action is provided by this worrying reality (Nyamekye et al., 2018). FAO (2010) estimated that rain-fed agriculture contributes to about 60% of the world crop production. However, on the African continent, 27% of the total land area has already been degraded, with 65% of it comprising of farmland (Dubois, 2011). Ninety five percent of the land in sub-Saharan Africa (SSA) is used for rainfed agriculture, while an estimated 41% of the population dwells in drought-prone areas (Biazin et al., 2012). The rate of productivity growth in African agriculture is the lowest in the entire globe (Biazin et al., 2012). Less than 2% of the world's irrigated land is located in SSA due to its costly nature and the physical water availability constraint (Kaluli et al., 2012).

The majority of smallholder farmers in Sub-Saharan Africa use the traditional farming system. The advantages are obvious: efficient seeding operations and successful weed control (Gichangi et al., 2007; Itabari et al., 2003; Ngetich et al., 2014). In contrast, this method of cultivation affects the amount of soil moisture retained, the rate of evaporation, and the susceptibility to runoff generation (Kebenei et al., 2021). Due to the exposure of surface soil, conventional tillage techniques are rarely environmentally sustainable and advantageous in terms of soil conservation and water management (Gathala et al., 2011; Liu et al., 2014; Obalum et al., 2019; Thierfelder & Wall, 2009; Zhao et al., 2021). Soil disruption brought on by frequent tillage encourages direct water vaporization from the soil surface, which furthers the apparent effect on erosion and runoff (Bottinelli et al., 2017; Shepherd et al., 2001). Due to the tilled surface's complete exposure, conventional tillage has also been linked to increased soil moisture evaporation (Miriti, 2011).

In developing countries, rainfed grain yields average 1.5 t ha^{-1} (Rosegrant et al., 2002) compared with 5-6 t ha^{-1} (Rockström & Falkenmark, 2000) in regions with reliable rainfall and sufficient nutrient availability (Clarke et al., 2017). The yield gap between the actual yields being harvested from farmers' fields and what could be potentially realized attests the need to develop new approaches of agricultural production in sub-Saharan Africa (Wani et al., 2009). Through the use of the appropriate technology, the challenge of low soil fertility and water scarcity has spurred more creative agricultural techniques to increase food security and subsistence, particularly for agricultural smallholder farmers(Nyang'au et al., 2021). A number of climate change interventions have been implemented to address the issues of water scarcity and low crop yields, including irrigation, planting trees, soil and water conservation techniques, and enhanced crop seeds (Gebru et al., 2020; Wawire et al., 2021).

These experiences suggest that the challenges of low yields in rainfed farming systems in developing countries might be overcome with nutrient management combined with soil water conservation (Rockström & Karlberg, 2010). Incorporating water harvesting technologies with improved soil fertility management methods generates synergies that further increase water efficiency and yields in smallholder farms (Winterbottom et al., 2013). Use of suitable water and soil management techniques such as zai pit (Evett & Tolk, 2009) increase rainfall use efficiency and bridge intra-seasonal dry spells (Dile et al., 2013).

Zai have been found to be capable of collecting up to 25% or more of a run-off coming from 5 times its area (Malesu *et al*., 2006). *Zai* pits are known to allow crops do well in areas with high risk of crop failure as a result of harsh climatic conditions (Critchley & Gowing, 2013). Water stored in the *Zai* pits delay the onset and occurrence of severe water stress thereby buffering the crop against damage caused by water deficits during dry periods (Nyamadzawo *et al*., 2013). The pits increase the amount of water stored in the soil profile by trapping or holding rainwater where it falls (Mutunga, 2001). Besides enhancing water storage, *Zai* pits increases water infiltration and reduces run-off for plant uptake during the dry periods (Danjuma & Mohammed, 2015).

II. ZAI PIT SYSTEM

Zai pit is a traditional dryland agricultural method that was developed in Burkina Faso, however some sources attribute it to the Dogon in Northern Mali (Danjuma & Mohammed, 2015). It entails using basins or holes with a depth of 10 cm to 15 cm and a diameter of 20 cm to carry out agricultural chores (Sawadogo, 2011). Since they guarantee soil upkeep, soil erosion control, and water preservation, their use has been found to reduce the consequences of droughts. This method has been utilized by farmers around the world to fight land degradation and restore soil fertility (Fatondji, 2002). According to the findings of Fatondji (2002), using Zai pits could improve nutrient usage efficiency, agronomic efficiency, and pearl millet crop output. In Burkina, Zougmoré *et al*. (2014) reported that *Zai* pit reduces runoff by increasing infiltration through creating and enhancing depressional water storage and reducing erosion.

A study by Sawadogo (2011) showed increased yields variations from 300 to 400 kg ha^{-1} by the *Zai* system in degraded land. Oduor *et al*. (2021) reported that *Zai* pit technique with manure increased crop yield. Sawadogo (2011) reported substantial grain yield increases where he reported sorghum yields increase in farmer's fields from 319-642 kg ha^{-1} without *Zai* pit system to 975-1600 kg/ha with *Zai* pit system. The use of *Zai* pit system has also been utilized in South Africa (Magombeyi & Taigbenu, 2008), Zambia (Thierfelder & Wall, 2009; Haggblade & Tembo, 2003), Ethiopia (Amede *et al*., 2011) and Niger (Fatondji *et al*., 2009) and in Zimbabwe (Gumbo *et al*., 2012).

In Kenya, *Zai* pits technology has been recommended as a water harvesting technique for the production of maize in the coastal region (Saha *et al*., 2007) and in the eastern region (Recha *et al*., 2014). Tumbukiza is a variation of the *Zai* pit technique that has been widely utilized by farmers in western Kenya as a method of napier grass production (Orodho, 2007). Variations of *Zai* pits have been used in various parts of Kenya including the katumani pit and 'five by nine' pit in Thraka nithi, Murang'a and Machakos Counties (Malesu *et al*., 2006).

III. Effects of Zai pit system on soil moisture

Water is an important factor of plant growth. In-situ soil moisture conservation entails capturing rainwater and retaining it in the soil for in-situ plant utilization for growth and increase in grain and biomass yield (Itabari & Wamuongo, 2003). Water harvesting and storage is vital to ensure water availability for plant growth especially in the arid and semi-arid areas. *Zai* have been found to be capable of collecting up to 25% or more of a run-off coming from 5 times its area (Malesu *et al*., 2006). *Zai* pits are known to allow crops do well in areas with high risk of crop failure as a result of harsh climatic conditions (Critchley & Gowing, 2013). Water stored in the *Zai* delay the onset and occurrence of severe water stress thereby buffering the crop against damage caused by water deficits during dry periods (Nyamadzawo *et al*., 2013). *Zai* pits increase the amount of water stored in the soil profile by trapping or holding rainwater where it falls (Mutunga, 2001). Besides enhancing water storage, *Zai* pits increases water infiltration and reduces run-off for plant uptake during the dry periods (Danjuma & Mohammed, 2015). The pits play a key water harvesting role. Instead of being lost to runoff, rainfall water is trapped in the *Zai* pits close to crop roots. *Zai* pits are especially relevant to areas receiving 300- 800 mm annual rainfall (Mwangi, 2020).

Despite their importance in increasing soil moisture in low rainfall areas, studies have also revealed the significance of using *Zai* pits in high rainfall areas with steep slopes. Such areas receive high rainfall but due to steep slopes, most of the water end up as run-off and results to massive soil erosion. A study by Amede *et al*. (2011) showed that *Zai* pits were effective in a highland area of Ethiopia that receives in excess of 1300 mm annual rainfall and where water infiltration into the soil is limited by losses of rainwater to runoff, a lack of organic matter, and hardpans. In their study Amede *et al*. (2011) found out that Crop water productivity of potato and beans was 300–700% higher with *Zai* pits than with control plots. In summary, the *Zai* system allows farmers to concentrate both fertility and moisture close to crop roots and, in so doing, addresses some of the major challenges to crop production in Sub-Saharan Africa (Mwangi, 2020).

IV. INTEGRATED SOIL FERTILITY MANAGEMENT (ISFM) TECHNOLOGY

Integrated soil fertility management (ISFM) is a means to increase crop productivity in a profitable and environmentally friendly way (Bationo & Waswa, 2011; Vanlauwe *et al*., 2010). It aims at offering wide-ranging solutions that are socially acceptable and practical in the management of soil fertility (Misiko, 2007). The ISFM paradigm became crystallized at the turn of the millennium with a new emphasis on improving the use efficiency of inorganic and organic fertilizer combinations while adapting nutrient management strategies to local conditions (Kolawole, 2013; Bationo & Waswa, 2011).

ISFM is a means to increase crop productivity in a profitable and environmentally friendly way (Vanlauwe *et al*., 2010), and thus eliminating one of the main factors that perpetuates rural poverty and natural resource degradation in sub-Saharan Africa (SSA). Current interest in ISFM results from global demonstration of the benefits of ISFM interventions, such as the combined use of organic manure and mineral

fertilizers (Zingore *et al*., 2008), dual purpose legume – cereal rotations (Sanginga & Woomer, 2009) or micro-dosing of fertilizer and manure for cereals in semi-arid areas (Tabo *et al*., 2007). ISFM is also aligned to the principles of Sustainable Intensification (Vanlauwe *et al*., 2014; Pretty *et al*., 2011), one of the paradigms guiding initiatives to increase the productivity of smallholder farming systems.

The benefits of ISFM technologies in enhancing fertilizer use efficiency and improving maize productivity are widely acknowledged in literature (Lambrecht *et al*., 2014; Mucheru-Muna *et al*., 2014; Fairhurst, 2012; Mugwe *et al*., 2009; Marenya & Barrett, 2007). According to Kamau *et al*. (2014), ISFM has the potential to reduce the need for chemical fertilizers owing to its ability to raise the efficiency of the applied nutrients. The adoption of ISFM technologies can also lead to economic benefits if gains in profits due to improved input productivity exceed the cost of adoption (Kamau *et al*., 2014). The use of inorganic and organic fertilizers such as compost manure, green manures, crop residues and legume integration in farming systems is one component of ISFM (Mhango *et al*., 2013). These organic fertilizers improve soil organic matter, nutrient and water retention in soils. ISFM technologies can enhance fertilizer use efficiency and thereby improve productivity (Fairhurst, 2012). Practices in ISFM technologies such as integration of legumes and incorporation of crop residues improve soil organic matter (Mucheru-Muna *et al*., 2010). Snapp *et al.* (2014) reported that rotating maize with a legume crop is another factor that consistently influences maize yield response to nitrogen. Use of ISFM technologies have led to increase in crop yields in many parts of SSA. Kaboré and Reij (2004) indicated that an additional dose of inorganic fertilizer and organic, in combination with the *Zai* pits and manure, increased yields by 640 kg ha^{-1} compared to the control treatment in Mali.

V. EFFECTS OF ZAI PIT SYSTEM COMBINED WITH ISFM TECHNOLOGY ON CROP YIELD

To increase crop yield, a variety of soil and water conservation techniques have been utilized (Getare et al., 2021). Numerous studies (Bedada et al., 2014; Bolo et al., 2021; Chen et al., 2017; Dunjana et al., 2012; Mucheru-Muna et al., 2007, 2014; Mugwe et al., 2009; Mutegi et al., 2012; Xu et al., 2018; Yuan et al., 2021) have demonstrated that the application of organics or in combination with inorganics increases the overall yield of the crops .The results of a study conducted by Fatondji *et al*. (2006) in Niger to examine the effect of *Zai* and organic amendments on millet grain yield reported higher yields in *Zai* plots as compared to the conventional ones, and 68 times more yields in *Zai* plots with manure amendments. In Kitui, the results of a study by Getare *et al*. (2021) revealed that all treatments under *Zai* system amended with organic inputs recorded significantly higher sorghum grain and stover yields compared to all similar treatments under conventional planting. Similarly, in Tharaka Nithi County, Kenya, Kimaru-Muchai *et al*. (2021) reported significantly higher sorghum grain and stover yields in treatments under *Zai* as opposed to similar treatments under conventional systems, with highest yields being recorded under *Zai* with organic amendments either solely or when combined with chemical fertilizer.

The utilization of Zai pits have been found to highly boost crop productivity. Kaboré & Reij (2004) discovered that *Zai* boosted sorghum yields by 310kg/ha compared to the treatments without *Zai* pits. Average yields in *Zai* pits in Niger's Illela area were 310% higher than untreated fields (Kaboré & Reij, 2004). *Zai* pits technology was found to have yielded much better dry matter yields than the traditional method in Western Kenya (Muyekho *et al*., 2000). Bationo *et al*. (2007) discovered that using *Zai* alone did not boost yields as much as using *Zai* in combination with manure and fertilizer in West Africa. In Niger, manure application with *Zai* increased grain yields by 2 to 69 times as opposed to *Zai* with no treatment (Fatondji *et al*., 2009).

In the highlands of Ethiopia, Amede *et al*. (2011) demonstrated the effectiveness of *Zai* pits by reporting a 500 percent to 2000 percent and up to 250 percent increase in potato and bean yields, respectively, when *Zai* pits were used in conjunction with nitrogen inputs compared to the control. Similarly, Sawadogo (2011) reported 100% increased crop yields on farms which employed the use of *Zai* pit technology as compared to the 63–74% increase on farms utilizing rock bunds in the study villages. Similar findings were reported by Zougmoré *et al*. (2004) who found that *Zai* had significantly influenced yields, especially when combined manure and chemical fertilizers are used. Even in the absence of *Zai* pits, several studies have demonstrated the positive influence of integrated soil fertility management options on crop yield. Mucheru-Muna *et al*. (2007) reported that treatments with organic (tithonia) amendments, with or without half recommended rate of mineral fertilizer, gave the highest maize grain yield compared to sole nitrogen treatments while the control treatment consistently gave the lowest yield across all the seasons.

Similarly, Mucheru-Muna *et al*. (2014) also reported that treatments with sole organics and those with combined organics and mineral fertilizers significantly increased maize grain yield compared with treatments with the recommended rate of sole mineral fertilizer (60 kg N ha^{-1})

and the unfertilized control. Kebenei et al. (2021) reported higher sorghum yields in Zai treatments with combined organic and inorganic amendments. Similarly, Oduor *et al*. (2021) reported better yield performance in treatments under *Zai* system which recorded 30.5% and 27.9% higher yields against 18.2% and 22.5% in conventional plots in Machakos and Naivasha, respectively. Several other previous studies have documented higher crop yields in *Zai* treatments whether solely or when utilized with sole organic inputs or integrated organic and inorganic inputs (Getare *et al*., 2021; Mwangi, 2020; Njue *et al*., 2020; Adamtey *et al*., 2016; Kathuli & Itabari, 2015; Recha *et al*., 2014; Fatondji *et al*., 2012; Amede *et al*., 2011; Sawadogo, 2011 Drechsel *et al*., 1999).

VI. FACTORS AFFECTING THE ADOPTION OF ZAI PITS

One of the crucial requirements for agricultural development, particularly in arid and semi-arid regions, is the adaptation and use of water harvesting systems(Danquah et al., 2019). Higher returns to farm production are the main driver of agricultural growth in every nation (Koome, 2017). To raise returns, farmers must embrace agricultural techniques that boost output and manage resources like soil and water more wisely, effectively, and sustainably for the environment (FAO, 2010, 2011).

Despite the technology created and put to the test on farms by various research individuals and institutions, farmers' adoption and implementation levels remain poor, resulting in persistently low productivity (Nyamadzawo et al., 2013). According to a study by (Mango et al., 2014), poor adoption of new technology and ineffective methods for managing soil fertility jeopardize smallholder farmers' ability to produce food sustainably and securely. Due to variations in socio-cultural, economic, and biophysical settings, different factors contribute to zai pits adoption and utilization from place to location and from one household to another (Amsalu & de Graaff, 2007). In their study of the factors influencing the adoption and use of zai and mulching in north Burkina Faso, (Slingerland & Stork, 2000) discovered that farmers who applied zai pits had larger households, more transportation options, and more livestock, which is congruent with their requirement for labor and manure.

Bett (2006) highlighted that a number of factors, including age and educational level, have a favorable or negative impact on the adoption of agricultural technologies. Marenya and Barrett (2007) discovered that greater education has a beneficial impact on adoption decisions because it is linked to the capacity to synthesize more information about the technologies that are available, which enhances the general management of the farm. On the other hand, Mutuku et al. (2016) argued that greater education may open up more career alternatives for a household head, leaving them with less time to devote to farm duties, which would negatively impact the uptake of agricultural-related technologies.

According to (Barry et al., 2009), the Zai Pits need roughly 300 hours of labor per ha.on the other hand, Kaboré and Reij (2004) stated that Zai system is more feasible when carried out by groups of farmers as opposed to individuals because it takes 450 hours/ha to dig the holes and an additional 250 hours/ha to fertilize them. This implies that wealthier farmers may be better placed to gain more from the technology. Several researchers (Gebru et al., 2020; Murgor et al., 2013; Mutuku et al., 2016; Njenga et al., 2021) have indicated that financial concerns, such as the high cost of hired labor, transporting agricultural products, construction materials, and the lack of credit access or lack of capital, are a barrier to farmers embracing contemporary agricultural inputs and technology such as Zai pits. The users' perception of the characteristics of a technology has been found to be an important determinant to its adoption (Koome, 2017).

In Burkina Faso, Sidibé (2005) discovered that factors including education and attitudes toward soil degradation served as the foundation for the utilization of the zai technique. According to (Wildemeersch et al., 2015), the use of zai pit technology in Niger is constrained by a lack of understanding of erosion and other crucial resources including manure, agricultural machinery, and transportation infrastructure. The high potential for zai pit adoption demonstrated by farmers in the most parts could be related to favorable institutional characteristics such an integrated lead farmer strategy and a well-structured extension system (Ndah et al., 2014; Nyanga, 2012).

Even in the presence of all the above researched on and established factors that determine the adoption of proven sustainable agricultural interventions for improvement of crop productivity, there is still low adoption and utilization of agricultural technologies like Zai pits and integrated soil fertility management technologies among farmers in sub-saharan Africa (Danquah et al., 2019). This poor adoption of new technology and effective methods for managing soil fertility has in the long-run jeopardized farmers' ability to produce food sustainably and securely to meet both subsistence and commercial needs.

VII. CONCLUSION

The aim of this study was to review relevant literature on the potential of Zai pit and integrated soil fertility management technologies to enhance agricultural

productivity and the factors affecting the adoption and utilization of the Zai farming technique. The reviewed literature has indicated that many past researches and experiments indicated high crop productivity in treatments with Zai pits especially when combined with integrated soil fertility management options. It has also been established that a number of factors, including perception, level of education, age and financial status of a household, has a great influence on its ability and willingness to adopt and utilize sustainable and effective agricultural interventions and technologies such as Zai pits for improved crop productivity. Reviewed literature also indicate that the adoption and utilization rates of Zai pits among farmers in sub-saharan Africa is still low and this could be attributed to other factors such as institutional characteristics and the lack of a well-structured extension system. Based on the findings, this study recommends that intensive education, awareness creation and training should be done among farmers in the sub-saharan Africa region to educate and raise awareness of the advantages of adopting and utilizing Zai and integrated soil fertility management technologies in their farms for improved crop productivity.

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Pattern Analysis and Marketing Efficiency of Bokar in Rural Area, Batanghari Regency, Indonesia

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Abstract— *Marketing is said to be efficient if it is considered capable of distributing products from farmers to the crumb rubber industry at a reasonable cost and a fair distribution of the price paid by the crumb rubber industry. For this reason, this study aims to analyze the marketing efficiency of bokar. This research was conducted in the Rural Area of Batanghari Regency, with a sample size of 77 farmers. Sampling uses the sSimple Random Sampling method. The data analysis used is quantitative descriptive analysis. with the One Way Anova test. Bokar marketing in Batanghari Regency consists of three marketing channels, namely: (1) Farmers - Auction Market - Provincial Collector Traders (PPProv) - Factory (Crumb Rubber). (2) Farmers - Village Collector Traders (PPD) - Provincial Collector Traders (PPProv) - Factory (Crumb Rubber). (3) Farmers - Provincial Collector Traders (PPProv) - Factories (Crumb Rubber). Based on the efficiency indicators of bokar marketing through marketing margin, farmer's share and profit ratio and marketing cost of bokar marketing channel I is more efficient than channels II and III. Based on the results of the One Way Anova test, the farmer's share received by bokar farmers in marketing channel I, marketing channel II and marketing channel III there is a significant difference. This means that the existence of a bokar auction market pool is able to significantly increase the efficiency of bokar marketing, and for this it is necessary to establish auction market poo in other villages.*

Keywords— ***bokar, marketing channel, efficiency, margin, farmer share***

I. INTRODUCTION

In Jambi Province, rubber commodity is one of the plantation commodities which has an important role in the economy. Rubber is an export commodity that contributes a lot to the country's foreign exchange besides oil and gas. There are five rubber-producing provinces in Indonesia, one of which is Jambi Province (Indonesian Rubber Statistics, 2018). Rubber commodities are spread in almost all regions in Jambi Province, including Batanghari Regency. Based on data (Plantation Office of Jambi Province, 2020) Batanghari Regency is an area that cultivates rubber plantations with the fourth largest land area after Bungo, Muaro Jambi and Sarolangun Regencies, which cover an area of 113,576 ha with a production of 75,357 tonnes and a productivity of 945 kg/ha. The wide distribution of rubber plantations in Batanghari Regency is in all Districts. Bajubang District is one of the Districts whose residents work as rubber farmers. The area of rubber plantation area is 22,944 ha with a production of 16,464 tons and productivity reaching 965 kg/ha.

The marketing of rubber plantation products is in the form of Processed Rubber Materials (Bokar). In the process of marketing bokar, the price of rubber received by farmers is different, due to the length of the marketing channel from farmers to final consumers. Marketing of Processed Rubber Materials (Bokar) has three marketing channels, namely first, rubber farmers sell their bokar through the Auction Market marketing channel, and secondly, rubber farmers sell their bokar. to Village Collector Traders (PPD) and the three rubber farmers sell their bokar to Provincial Collector Traders (PPProv). The price for bokar on the auction market for the period August - September 2022 is Rp. 10,000 – Rp. 11,000, - and the price of bokar at the collectors in the same period is Rp. 9,000 – Rp.

10,000,- / kg. Fewer farmers sell to the auction market through the Bokar Processing and Marketing Unit (UPPB) than farmers who sell to collectors. In terms of the purpose of forming an auction market is to increase production, rubber farmers' income, the price of the auction market is more open, the marketing of bokar is carried out simultaneously at one time, and there is uniformity in the quality of bokar (Kurniati et al., 2020). Meanwhile, the price for collecting traders is determined based on the provisions of the collecting traders themselves. The number of farmers who sell to collectors on the basis of engagement and socio-economic factors. The long bokar marketing channels and the low prices received by farmers have caused problems with the bokar marketing system.

In bokar marketing, rubber farmers occupy a less profitable bargaining position. Marketing institutions that are heavily involved in bokar marketing cause differences in prices received by farmers through the auction market and collectors. According to (Sutoyo et al., 2017) marketing agencies are basically intermediaries for producers. Analyzing marketing efficiency of bokar. Analyzing differences in farmer's share received by farmers in each bokar marketing channel in Batanghari Regency

II. RESEARCH METHODS

This research was conducted in Batanghari District, Bajubang District, with the research locus in Ladang Peris Village and Panerokan Village. The selection of the research location was carried out purposively with the consideration that the village was served by a rubber auction market pool. The size of the sample taken was determined using Taro Yamane or the slovin method with a precision of 15% (Ridwan and Akdon, 2009). The bokar farmer population and sample can be seen in Table 1:

Table 1. Population and Sample of Bokar Farmers in Research Area, 2022

No.	Market Name	Total Population	Total Sample
1.	Auction Market	150	34
2.	Non Auction Market	1.039	43
	Total	**1.189**	**77**

The sampling of farmers was carried out using the simple random sampling method.

Methods of data analysis using quantitative descriptive analysis to analyze the marketing efficiency of bokar from the aspect of marketing margins, farmer's share and profit and cost ratios.

a. Marketing Margins

$M = He - HP$

Where :

M : Marketing margin (Rp)

He : Price paid by consumers to marketing agencies (Rp)

Hp : Rubber Producer Price (Rp)

b. Farmer's Share

$Fs = Pf/Pr \times 100\ \%$

Where :

Fs : Farmer's share of farmers (%)

Pf : Bokar price at farmer level (Rp)

He : Bokar prices at the end consumer level (Rp)

If the farmer's share value is ≥ 40%, marketing is said to be efficient and if the farmer's share value is ≤ 40%, marketing is said to be inefficient (Fatima et al., 2022).

c. Profit and Cost Ratio

Profit and Cost Ratio = Li/(Ci)

Where:

Li: Profits of marketing agencies

Ci : Marketing costs

If $\pi/c > 1$, then the marketing activity is said to be efficient, and can be continued. Whereas $\pi/c < 1$, the marketing activity is said to be inefficient, so it will be detrimental if it continues to be carried out (Fatima et al., 2022).

d. One Way Anova test

According to (Muhson, 2016) the purpose of one way ANOVA is to test the average difference of more than two groups of data. To test differences in farmer's share of marketing channels, a one-way ANOVA test was carried out. With a hypothesis

H_0 : There is no difference in farmer share based on bokar marketing channels.

H_a : There are differences in farmer share based on bokar marketing channels

III. RESULTS AND DISCUSSION

Bokar Marketing Channel

Marketing is a process of distributing goods or services that involves marketing institutions (Nasrudin and Musyadar, 2018). Bokar marketing involves farmers as producers, collectors and rubber auction market.

From the results of the study, it was found that there were differences in the bokar marketing paths taken by farmers to go to the factory (Crumb Rubber), namely that there were 3 marketing channels found. First, the bokar marketing channel through the rubber auction market, 44.2% of farmers selling bokar at the rubber auction market. The two bokar marketing channels are through village collector traders (PPD), farmers who sell bokar to PPD as much as 14.3%. The three bokar marketing channels are through Provincial Collector Traders (PPProv), farmers who sell bokar to PPProv as much as 41.6%. The bokar marketing channels in the research area can be seen in Figure 1.

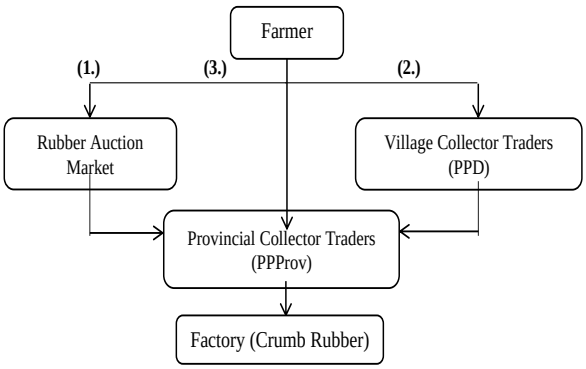

Fig.1. Bokar Marketing Channel, Batanghari Regency

Bokar Marketing Costs, Profits and Margins

Bokar marketing starts from farmers as producers to the crumb rubber industry. The costs, profits and marketing margins in the marketing channel I bokar can be seen in Table 2

Table 2. Costs, Profits and Marketing Margins of Bokar Marketing Channel I 2022

Description	Rp/kg	%
The selling price of farmers to the auction market	10.778	82,91
Cost:		
Transportation	41	0,32
Unload and load	90	0,69
Consumption	3	0,02
Sorting	-	-
Storage	-	-
Tax	15	0,12
shrinkage	-	-
Total cost	149	1,15
Profit	-149	-1,15
margins	-	-
PPProv purchase price from the auction market	10.778	82,91
Cost:		
Transportation	46	0,36
Unload and load	105	0,81
Sorting	-	-
Storage	-	-
Tax	15	0,12
shrinkage	90	0,69
Total cost	256	1,97
Profit	1.966	15,12

margins	2.222	17,09
Factory selling price	13.000	100

Table 2 shows that in marketing channel I, the average price received by farmers from the auction market is Rp. 10,778 / kg, while the price for Provincial Collectors to Factory (Crumb Rubber) is IDR 13,000 / kg, there is a price difference between the auction market and the factory, the price difference is due to marketing costs and profits from each marketing agency involved. The marketing margin from the price received by bokar farmers minus the price paid by the factory is Rp. 2.222/kg. Bokar marketing costs incurred in marketing channel I amounted to Rp. 405/kg. The marketing profit obtained is Rp. 1,817 / kg, (Khaswarina et al., 2018) marketing profit is the difference between marketing margin and marketing costs.

The reason farmers sell their bokar at the rubber auction market is because the auction market processes the bokar weighing more transparent than selling to collectors, and the price received by farmers is also transparent. The quality of the bokar (dry rubber content) is also of great concern on the auction market because the quality of the bokar will determine the price, the dry rubber content (KKK) of bokar sold by farmers must be 50-60%. The costs, profits and marketing margins on the Bokar II marketing channel can be seen in Table 3.

Table 3. Costs, Profits and Marketing Margins of Bokar Marketing Channel II 2022

Description	**Rp/kg**	**%**
Selling price of farmers to PPD	9.300	71,54
Cost:		
Transportation	-	-
Unload and load	60	0,60
Sorting	-	-
Storage	-	-
Tax	15	0,12
shrinkage	90	0,69
Total cost	165	1,27
Profit	490	3,77
margins	655	5,03
Selling price of PPD to PPProv	9.955	76,57
PPPprov purchase price	9.955	76,57
Cost:		
Transportation	180	1,38
Unload and load	105	0,81
Sorting	-	-
Storage	-	-
Tax	15	0,12
shrinkage	90	0,69
Total cost	390	3,00
Profit	2.655	20,43
margins	3.045	23,43
Factory selling price	13.000	100

Table 3 shows that the marketing channel II through Village Collector Traders (PPD), the average selling price of bokar from farmers to Village Collector Traders (PPD) is Rp. 9,300 / kg, the selling price of bokar from Village Collector Traders (PPD) to Provincial Collector Traders (PPProv) is Rp. 9,955 / kg, while the selling price of Provincial Collector Traders to the Factory (Crumb Rubber) is IDR 13,000 / kg. There are price differences between PPD, PPProv and factories, these price differences are due to marketing costs and profits from each of the marketing agencies involved. Bokar marketing costs incurred on channel II amounted to Rp. 555/kg. Marketing profit of Rp. 3.145/kg. The marketing margin obtained is Rp. 3,700/kg. This means that the longer the bokar marketing channel is traversed, the greater the marketing margin received by the collecting traders, because there are many marketing agencies that take advantage. Consistent with Sutaryadi et.al (2021) the more intermediaries in the marketing channel, the longer the marketing level. The reason farmers sell bokar to Village Collector Traders (PPD) is because there is no time limit for farmers to sell bokar to Village Collector Traders, it is easy for farmers to get loans. Village Gathering Traders will personally come to the farmer's house to buy bokar. The location of the factory which is far away causes farmers to prefer to sell their bokar to Village Collector Traders. The costs, profits and marketing margins on marketing channel III bokar can be seen in Table 4.

Table 4. Costs, Profits and Marketing Margins of Bokar Marketing Channel III 2022

Description	Rp/Kg	%
Selling price of farmers to PPProv	**9.681**	**74,47**
Cost:		
Transportation	**52**	**0,40**
Unload and load	**140**	**1,08**
consumption	**5**	**-**
Sorting	**-**	**-**
Storage	**-**	**-**
Tax	**15**	**0,12**
shrinkage	**90**	**0,69**
unexpected costs	**10**	**-**
Total cost	**312**	**2,40**
Profit	**3.007**	**23,13**
margins	**3.319**	**25,53**
Factory selling price	**13.000**	**100**

Table 4 shows that marketing channel III is through Provincial Collector Traders (PPProv), the average selling price of farmers to Provincial Collector Traders (PPProv) is Rp. 9,681 / kg, while the selling price of Provincial Collector Traders to the Factory (Crumb Rubber) is IDR 13,000 / kg. There is a price difference between the Provincial Collector Traders (PPProv) and the factory, (Tarmizi, 2007) that the collector traders take advantage of the sale of daily necessities and also the results of buying rubber from farmers who are subject to cuts and deception of the scales they use. Bokar marketing costs incurred on channel III amounted to Rp. 312/kg. Marketing profit of Rp. 3.007/kg. Marketing margin of Rp. 3.319/kg. Farmers choose to sell bokar to Provincial Collector Traders (PPProv) because these traders provide convenience for farmers in borrowing money such as to meet basic family needs, school children's fees, medical expenses and party expenses, and fast marketing service processes. The return of money borrowed by farmers is done by cutting directly from the bokar sold by farmers to pay off the farmers' debts.

Marketing Efficiency

(Sutaryadi et al., 2021) that marketing efficiency is said to be efficient if it is considered capable of conveying results from producers to consumers at a reasonable cost and a fair distribution of the prices paid by consumers. Bokar's marketing efficiency is seen from marketing margins, farmer's share and profit and cost ratios.

Marketing Margins

The marketing margin is the difference between the price at the farmer producer level and the price at the final consumer level. Marketing margin includes all marketing costs and profits during the bokar marketing process from each marketing channel (Fahrurrozi et al., 2012). Marketing margins based on bokar marketing channels can be seen in Table 5.

Table 5. Bokar Marketing Margin Calculation Based on Marketing Channels, 2022

Marketing channel	Average Purchase Price at Farmer Level (Rp)	Average Selling Price at End Consumer Level (Rp)	Marketing Margin (Rp)
I	10.778	13.000	2.222
II	9.300	13.000	3.700
III	9.681	13.000	3.319

Source: Results of Processed Primary Data 2022

Table 5 shows that in marketing channel I the value of marketing margins is smaller compared to marketing channels II and marketing channels III. This means that the bokar auction market can increase the efficiency of the marketing channel. Research (Apriyanti and Ramadhani, 2018) states that the lower the value of the marketing margin obtained, the more efficient the marketing channel will be. According to (Situmorang et al., 2015) the amount of marketing margin earned in each marketing channel is influenced by sales volume, distance to marketing locations, length of marketing channels and marketing functions performed.

Farmer's share

Farmer's share is the percentage of the price received by farmers with the price paid by the final consumer. Farmer's share is inversely proportional to the marketing margin, the higher the marketing margin, the lower the farmer's share received by farmers (Apriyanti and Ramadhani, 2018). Farmer's share based on bokar marketing channels can be seen in Table 6.

Table 6. Bokar Farmer's Share Calculation Based on Marketing Channels, 2022

Marketing channel	Average Price at Farmer Level (Rp)	Average Selling Price at End Consumer Level (Rp)	*Farmer's Share (%)*
I	10.778	13.000	82,91
II	9.300	13.000	71,54
III	9.681	13.000	74,47

Source: Results of Processed Primary Data 2022

Table 6 shows that in marketing channel I the prices received by farmers are higher, in contrast to marketing channel II the prices received by farmers are smaller, meaning that the size of the farmer's share does not always indicate the size of the profits received by farmers. The large number of marketing agencies involved in the marketing channel makes the selling price of bokar at the farm level different and the price paid by consumers is lower, even though the price paid by the final consumer is higher. Consistent with research (Khaswarina et al., 2018) the greater the value of the farmer's share, the higher the bokar price received by farmers, so that the bokar marketing channel becomes efficient. According to (Fatima et al., 2022) explains that if the farmer's share value is ≥ 40% then marketing is said to be efficient and if the farmer's share value is ≤ 40% then marketing is said to be inefficient. According to (Iswahyudi and Sustiyana, 2019) states that the large value of the farmer's share does not always indicate that the marketing channel is efficient.

Profit and Cost Ratio

The profit and cost ratio is a comparison between the costs incurred and the profits generated (Putri et al., 2018). The higher the value of the ratio the greater the profit earned. The ratio of benefits and costs based on marketing channels can be seen in Table 7.

Table 7. Calculation of Profit Ratios and Bokar Costs Based on Marketing Channels, 2022

Marketing channel	Total Profit (Rp)	Total Marketing Expenses (Rp)	Profit and Cost Ratio
I	1.817	405	4,49
II	3.145	555	5,67
III	3.007	312	9,63

Source: Results of Processed Primary Data 2022

Table 7 shows that the value of the profit and cost ratio for each bokar marketing channel has results > 1, meaning that every bokar marketing institution has profits and is feasible to run. According to (Fatima et al., 2022) if $\pi/c > 1$, then the marketing activity is said to be efficient, and can be continued. While $\pi/c < 1$, the marketing activity is said to be inefficient, so it will actually be detrimental if it continues to be carried out. According to (Irawan et al., 2021) states that each marketing channel has a different ratio of benefits and costs, with an even distribution of the value of the ratio of benefits and costs in each marketing institution, the marketing is technically more efficient.

Marketing Efficiency Analysis

Marketing margins, farmer's share, and profit and cost ratios, based on bokar marketing channels can be seen in Table 8.

Table 8. Bokar marketing efficiency based on marketing margin, farmer's share and profit and cost ratio, 2022

Marketing channel	Marketing margin (Rp)	*Farmer's share (%)*	Profit and cost ratio
I	**2.222**	**82,91**	**4,49**
II	**3.700**	**71,54**	**5,67**
III	**3.319**	**74,47**	**9,63**

Table 8 shows that the bokar marketing channels are not categorized as efficient because seen from three

aspects of efficiency the results obtained on each bokar marketing channel do not show efficiency, the efficiency requirements of the bokar marketing channel have a smaller marketing margin value, meaning the lower the marketing margin value obtained on the marketing channel bokar, then the marketing channel becomes efficient. The farmer's share value in the marketing channel must be greater, meaning that the greater the farmer's share value obtained in the bokar marketing channel, the greater the bokar price received by farmers, so that the bokar marketing channel becomes efficient. The value of the profit and cost ratio in the marketing channel must be greater than 1, meaning that the bokar marketing channel has advantages and is feasible to run, and can be said to be efficient. Based on research (Stevan et al., 2015) that economically the marketing channel through collectors is more efficient than through the auction market marketing channel.

One Way Anova test

The one-way ANOVA test is a parametric statistical test that aims to test the difference in the mean or more of two groups of data or samples (Susilawati et al., 2021). To examine differences in farmer's share received by bokar farmers, through bokar marketing at the auction market and collecting traders based on marketing channels I, II and III. The results of one way ANOVA testing on marketing channel I, marketing channel II and marketing channel III bokar can be seen in Table 9.

Table 9. Hasil uji One Way Anova Farmer's Share Petani Bokar Pada Saluran Pemasaran I, II dan III 2022

	Sum of Squares	Df	*Mean Square*	F	Sig.
Between Groups	**1672.730**	**2**	**836.365**	**91.203**	**.000**
Within Groups	**678.606**	**74**	**9.170**		
Total	**2351.336**	**76**			

Table 9 shows that the results of the one way ANOVA test obtained a test value (sig) = 0.000 <alpha 0.005, then Ho was rejected. This means that there is a significant difference in farmer's share received by bokar farmers in marketing channel I, marketing channel II and marketing channel III. From the multi-comparison test seen from the Tukey HSD and LSD tests, it was found that there were significant differences (Appendix 8). The results of the Tukey HSD test showed that marketing channel I had a difference with marketing channel II and marketing channel III with a sig value of 0.000. However, for marketing channel II and marketing channel III there is no difference because the sig value > 0.005 is 0.019. The results of the LSD test also showed that marketing channel I was different from marketing channel II and marketing channel III with a sig value of 0.000. However, for marketing channel II and marketing channel III there is no difference because the sig value > 0.005 which is equal to 0.007.

IV. CONCLUSION

Bokar marketing in Batanghari Regency consists of three marketing channels, namely: (1) Farmers - Auction Market - Provincial Collector Traders (PPProv) - Factory (Crumb Rubber). (2) Farmers - Village Collector Traders (PPD) - Provincial Collector Traders (PPProv) - Factory (Crumb Rubber). (3) Farmers - Provincial Collector Traders (PPProv) - Factories (Crumb Rubber). Based on the efficiency indicators of bokar marketing through marketing margin, farmer's share and the profit and cost ratio of marketing bokar marketing channel I is more efficient than channels II and III. Based on the results of the One Way Anova test, the farmer's share received by bokar farmers in marketing channel I, marketing channel II and marketing channel III there is a significant difference. This means that the existence of a bokar auction market pool is able to significantly increase the efficiency of bokar marketing, and for this it is necessary to establish auction market poo in other villages.

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A Perception-Based Survey on Innovation and Technology Adoption by Small-Scale Farmers in Semi-Arid Zimbabwe

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Abstract— *This study was conducted with agricultural extension agents of semi-arid Zimbabwe to gather their perceptions on innovation and technology adoption by small-scale resource-constrained farmers, as well as the effect of their working conditions on the quality of service delivery to small-scale farmers. Data was solicited through focus group discussions (FGDs) and semi-structured interviews (SSIs) with all the public agricultural extension agents operating in the study area. It was found that agents were mainly hampered by lack of in-service training, transport and poor remuneration. Of all disseminated technologies during the last 20 years, respondents assessed that 17% had very low adoption rate, 26% had low adoption, 17% had average adoption, 26% had high adoption and only 13% had very high adoption. Bulky, expensive and risky technologies like tractors, solar driers, metal silos and bee farming were among the least adopted whereas hybrid seeds and value addition were very highly adopted. Reasons for the very low adoption were noted to be lack of capital, markets and information support on how to use new technology. Despite these challenges respondents indicated that small-scale farmers had the capacity to innovate and to adopt technology in the form of indigenous knowledge, willingness and commitment to learn and improve productivity, and labor. Agents suggested the strengthening of farmer-extension-research linkages so that technologies could be developed from some successful indigenous innovations, where possible and also to ensure the development of technology tailor-made to the needs of small-scale farmers, resource-endowments and biophysical conditions of their farming communities.*

Keywords— ***Adoption, indigenous knowledge, innovation, small-scale farmers, technology.***

I. INTRODUCTION

Extension plays an important role of transferring technologies to small-scale farmers for adoption and in fostering development of innovations from among diverse actors [1,2]. Extension is also responsible for taking feedback from farmers to research and technology developers [3]. However, for extension to effectively and efficiently deliver quality service to their clients they need adequate resources and facilities, including transport for their agents to reach farmers and regular appropriate in-service trainings for agents to update their skills [1]. Unfortunately, the primary public extension agency in Zimbabwe, the Department of Agricultural Technical and Extension Services (AGRITEX), is faced with serious challenges hindering its service delivery [1, 4, 5]. Consequently farmers are not receiving optimal extension services from agents, who are poorly remunerated and with little or no motivation to do their job. This has led to less adoption of recommended technology by farmers. For these reasons, this study was conducted in Lower Gweru, a semi-arid communal area in Zimbabwe, to gather perceptions and assessments of agricultural extension agents on innovation and technology adoption by small-scale resource-constrained farmers, as well as the effect of their working conditions on the quality of service delivery they render to small-scale farmers. Lower Gweru communal area was selected from among semi-arid areas in Zimbabwe because it has recorded increased number of technologies disseminated over the last 20 years and it is also dominated by small-scale farmers.

II. MATERIAL AND METHODS

2.1. Study area description

The study was carried out with public agricultural extension agents operating in Lower Gweru Communal area of Zimbabwe, which is located about 40 km north west of City of Gweru, and stretches a further 50 km to the west [4]. Lower Gweru is a developed communal settlement in the Midlands province of Zimbabwe. Gweru's climate is semi-arid to arid with summer rainfall ranging from 450mm to 600mm annually but experiences periodic seasonal droughts and severe dry spells [4]. Farming is the main occupation of the people. Administratively (in terms of extension services), Lower Gweru Communal area falls under Gweru District AGRITEX. Lower Gweru is divided into eight Wards and these are: Sikombingo, Nyama, Mdubiwa, Chisadza, Madikani, Bafana, Nkawane and Communal Ward 16 [4]. Each of these Wards is serviced by two extension agents.

2.2. Data collection

The study explored perceptions of public agricultural extension agents and the effect of their working conditions on innovation and technology adoption innovation by small-scale resource-constrained farmers. The study population was composed of 16 field extension agents, two extension supervisors, two agricultural extension officers and the district agricultural extension officer. Due to the relatively low study population, all the 21 public agricultural extension agents were part of the study. Data were solicited using semi-structured interviews (SSIs) and focus group discussions (FGDs). The main questions in both SSIs and FGDs guides were about the following themes: job satisfaction level; rating the quality of services rendered to farmers, assessment of farmer capacity to innovate and adopt technology; technologies recommended/disseminated to farmers in the last 20 years; adoption rates for each technologyand reasons for adoption or lack thereof; and strategies aimed at promoting adoption. The collected data were triangulated for consistency with findings gathered from key informant interviews (farmers). The qualitative data gathered were transcribed verbatim and analyzed using the emergent theme approach.

III. RESULTS

Key findings are presented under three major themes namely: Effect of socio-economic characteristics of extension personnel on job performance; Extension personnel's perceptions on farmers' systems and their capacity to innovate and adopt technologies; Strategies suggested by extension agents to encourage technology adoption.

3.1. Effect of socio-economic characteristics of extension personnel on job performance

Findings presented under this theme are summarized under the following sub themes: Demographics of respondents; Quality of extension services rendered to farmers; Job satisfaction of extension agents; Challenges facing public extension agency (AGRITEX) and its workers.

3.1.1. Demographics of respondents

The extension personnel servicing the Lower Gweru Communal area comprised more females (57.1%) than males (42.9%). The majority (61.9%) of the respondents were in between 35 and 50 years old, with only 9.5% above 50 years of age (Table 1). The majority of respondents (66.7%) were educated up to diploma level, 23.8% had a Bachelors degree, and less than 10% were educated beyond the Bachelor's degree level (Table 1).

Table 1: Demographics and working experiences of respondents

Factor	Category	Frequency	Percentage
Gender	Male	9	42.9
	Female	12	57.1
Age group	< 35 years	6	28.6
	35 – 50 years	13	61.9
	>50 years	2	9.5
Working experience	5 – 10 years	9	42.9
	11 -30 years	11	52.4
	>30 years	1	4.7
Qualifications	Diploma	14	66.7
	Bachelors' Degree	5	23.8
	Honors' Degree	1	4.7
	Masters' Degree	1	4.7
Job Satisfaction	Yes	11	52.4
	No	7	33.3
	Indifferent	3	14.3
Rating extension services rendered to farmers	Poor	2	9.5
	Average	4	19
	Good	12	57.1
	Excellence	3	14.3

Source: Extension agents' responses from SSIs.

3.1.2. Quality of extension services rendered to farmers

Four groups emerged from respondents based on how they rated the services they render to farmers. They were asked to rate it as excellent, good, average or poor.

Excellent: 14.3% of the respondents rated their services to be excellent. Their reasons included that they are confident and well qualified for their jobs and have a high affinity for extension and rural development work. They cited no major challenges diminishing the excellence of their service.

Good: The majority of respondents (57.1%) rated their services to farmers to be good. Reasons for this rating included that farmers are getting most of the services they demand, improved farm production (crop yields and animal productivity), and improved quality of life for farmers. Further, these extension agents stated that most farmers quickly adopt techniques, practices and technologies they disseminate to them. The only reason this group did not rate their services to be excellent was due to several challenges that have affected their work especially lack of transport (mobility).

Average and poor: 19% rated their services to be average while 9.5% rated their services to be poor. These two groups cited the challenges they face including lack of resources (including transport) and regular in-service training as reasons for their ratings. They also indicated that the high extension agent-to-farmer ratio overburdens them to the point of compromising their service delivery.

Further, as the next two sections will demonstrate, the issues intimated in the assessment of the quality of services increase in prominence and are cited as inhibiting the quality of service. They openly state that, due to the resource issues, they are not able to meet their objectives without the help of private players.

3.1.3. Job satisfaction of extension agents

More than half (52.3%) of the respondents indicated that they enjoyed their work. Three reasons were given for this. First, extension work is challenging and interesting because of the positive impact the work has on farmers. Second, extension work comes naturally to them (it is a calling). Third, it allows respondents to interact with different farmers most of whom are co-operative and learns a lot from them. A third (33.3%) of the respondents indicated they do not enjoy their work. They explained that they are frustrated because of lack of resources and sometimes they are forced to use their own resources to get some work done. The respondents who indicated that they are indifferent (14.3%) cited a lot of challenges, especially lack of mobility. They also indicated that if most of their challenges were addressed they would enjoy their work. This aspect of the study underlines the issues raised in the extension agents' assessment of the quality of their services. Approximately 30% raised the issue of resource (specifically transport/mobility), here 33.3% raise the issue again as a key inhibiter to delivering extension.

3.1.4. Challenges facing AGRITEX and its workers

The main challenge facing AGRITEX and its workers is inadequate funding from the government. This challenge cascades into a plethora of problems ranging from lack of transport, lack of materials to use in demonstrating new technology, lack of capacity building opportunities within AGRITEX in the form of in-service training and refresher courses, poor remuneration and lack of travel and subsistence allowances as well as lack of modern training equipment for farmer trainings.

Although the government still has some accommodation in the respective Wards which should help alleviate transport and accommodation woes for field agents, the houses have not been maintained over the last decade. Thus, a considerable proportion of respondents (42.9%) indicated that they prefer to stay in the city and visit farmers when they can. However, this presents a situation that is not ideal for both agents and the farmers.

According to the elderly extension agents who were part of AGRITEX long before the economic challenges started in the early 2000s, they are no longer getting the back-up services and in-service training/refresher courses they used to get regularly previously. They stated that training used to be continuous and regularly conducted; thereby making sure the agents would remain competent and would not lag behind in terms of new advancements in technology. They noted that, currently, a few of the better educated and well-resourced farmers are utilizing new technologies in their operations which the extension agents are yet to learn about/or to disseminate to them. In fact, the respondents explained that there are instances where these "better-educated and resourced" farmers are better versed with new technologies than the extension agents who are supposed to be bringing technologies to them.

Due to the several challenges facing AGRITEX and its workers, respondents indicated that they are failing to execute their mandate and currently most of their work is being dictated by donors, researchers and NGOs operating in the Lower Gweru Communal area. These organizations will use own resources to implement certain programs with farmers including availing transport, training as well as some allowances to extension agents who facilitates and link them with farmers. As these organizations conclude their projects and programs, extension agents will again experience their challenges in accessing farmers due to lack of resources.

Furthermore, respondents indicated that farmers are more eager to participate in programs funded and led by donors/NGOs as opposed to AGRITEX-led programs. Reasons for this include that in donor-funded programs, farmers get inputs and other technologies for free; and they participate in the actual testing of technology in their fields. In other words, they are learning by doing. However, the respondents indicated that while they still participate as facilitators or brokers in this pluralistic extension setup, they are no longer able to meet their own Departmental objectives without private-sector support.

The combination of a poor road network and lack of transport often leads to late delivery of inputs and technologies. Consequently, the adoption of such technologies delivered late into the season is usually poor. This does not reflect well on the agents and may result in loss of trust and credibility by farmers towards agents and the technologies they disseminate.

One respondent indicated that AGRITEX, as an extension service provider, is lagging behind in terms of the technologies they are disseminating to farmers, as some of them are out-dated. The respondent further indicated that agents are actually learning some modern technologies from farmers who, in turn, have learned from private sector consultants. Finally, the respondents indicated that training should be continuous, as new developments and technologies always come up.

3.2. Extension agents' perception on farmers' systems and their capacity to innovate and adopt modern technology

Findings presented under this theme are summarized under the following sub themes: Farmer capacity to innovate and adopt modern technology; Extension agents' perception of farmers' indigenous knowledge/technologies; Assessment of adoption rates for each technology disseminated to farmers.

3.2.1. Farmer capacity to innovate and adopt modern technology

The extension respondents indicated that, despite constraints facing small-scale farmers in adopting technologies or in innovation, they possess some important capabilities and resources. The agents identified capacity in the form of local knowledge and experience, land (including some wetlands), tools and implements, animal traction power, labor, resilience and commitment. Further, the respondents suggested that farmers are literate, open-minded and always willing to learn wherever their livelihoods are concerned. Finally, they perceive the farmers to be very observant and innovative, especially when their livelihoods are at risk.

3.2.2. Extension agents' perception of farmers' indigenous knowledge/technologies

The general perception of extension personnel towards farmers' indigenous traditional knowledge is that it is valuable, helpful and a useful source of information; that has and still continues to serve farmers well. Respondents posited that farmers' indigenous knowledge and experiences complements extension agents' skill sets.

The respondents also noted that indigenous knowledge and its associated technologies are very low cost in nature and are accessible and affordable to all farmers, unlike most modern technologies. The respondents identified some of the successful innovations and indigenous practices developed by farmers including: seasonal climate forecasts through studying local indigenous indicators; crop rotations; intercropping cereals with runner crops like pumpkins to reduce erosion; seed retention for main crops like maize (open pollinated varieties), cowpeas, beans and groundnuts; curing maize cobs by smoke for maize seed; use of ash, zumbani and gumtree leaves in grain storage for repelling weevils; castration of bulls to control livestock breeding; control of maize stalk borer and aphids using sand and donkey manure, respectively.

Despite the numerous advantages of farmers' indigenous knowledge, respondents noted its three major drawbacks. First, it is not documented and can only become more useful if it is recorded adequately (including visually) and developed further with help from scientists. Second, it has been an impediment to technology adoption as farmers are generally resistant to change and slow in accepting outside help including new modern technology. Third, it is perceived to be one of the major reasons why farmers have been stagnant and failing to advance to the next level of processing their raw crops.

3.2.3. Assessment of adoption rates for each technology disseminated to farmers

The respondents indicated that technology adoption is generally declining because of the poor service delivery by AGRITEX due to economic hardships facing the country. Similarly, farmers have also been affected by these economic challenges. This has resulted in some respondents indicating issues of false adoption, whereby farmers adopt some technologies only because they are given it free of charge. This is most apparent where high cost technologies are concerned, such as instances where NGOs were supplying some few samples of technologies to farmers. Table 2 shows a variety of technologies disseminated to Lower Gweru farmers and the adoption rates for each as perceived by respondents. Five adoption rate categories emerged namely: very low, low, average,

high and very high. These adoption rate categories were estimated and agreed upon by respondents during FGDs as follows: Very Low – less than 20 %; Low – from 20 % to 45 %; Average – 45 % up to 60 %; High – 60 % up to 80 %; Very High – 80 % up to 100 %. Of all disseminated technologies during the last 20 years, respondents assessed that 17% had very low adoption rate, 26% had low adoption, 17% had average adoption, 26% had high adoption and only 13% had very high adoption. Bulky, expensive and risky technologies like tractors, solar driers, metal silos and bee farming were among the least adopted whereas hybrid seeds and value addition were very highly adopted

Table 2: Technologies disseminated to Lower Gweru Communal area farmers and the respective adoption status for each

Technology	**How disseminated**	**Adoption rate**	**Reasons for adoption rate**
Conservation agriculture	Demonstrations and training	High	Improved yields on maize and sorghum. Helpful especially to farmers without draft power as there is no need for ploughing.
Treadle pump	Demonstration	Low	Despite subsidies offered by Donor it was still costly and unaffordable to farmers. Poor water source also resulted in poor adoption.
Poultry (Layers production)	Training and pamphlets	Average	Relatively high costs of setting up and feed. Benefits like manure and eggs for income generation led farmers who afford the costs to adopt.
Bee farming	Demonstrations and training	Very low	Considered high risk by farmers. Male farmer-dominated adoption.
Value addition	Demonstrations	Very high	Nutritional benefits, increased income from selling multiple products from sweet potatoes.
Thermal compost	Demonstrations	High	Cheap source of fertilizer and highly favored by farmers without cattle.
Artificial Insemination and animal breeding	Pioneer farmer groups. Training and demonstrations	Low	High costs of semen and fridges, and unavailability of semen. Some farmers particularly with few animals were skeptical of this technology.
Crop protection herbicides (IPM)	On-farm trials and training	Low	They are expensive and cultural beliefs (myth) that they deplete nutrients status of the soil and unavailability of information on how to use.
Seedbed management	Demonstrations	High	High quality seeds and minimized incidence of diseases.
Metal Silos	Demonstrations	Very low	Highly regarded but costly for farmers
Groundnuts roasters	Training and demonstration	Low	Highly regarded because it is easier, smarter, faster and less risk of getting burnt; saves fuel as large quantities are processed at once. The cost of technology is high.
Livestock feeds (Silage)	Demonstrations	High	Easy to make, reduce wastages and its cheaper supplements for livestock.
Moisture conservation	On-farm trials and demonstrations	Average	Resulted in better yields even in low rainfall seasons.
Solar driers	Demonstrations	Very low	Highly regarded because its ability to preserve surplus produce but very costly for farmers.
Cell phones	Network providers	Very high	Useful in conveying messages on time. No information distortions as farmers get message from agents directly.
Crop simulation models/outputs	Training, pamphlets and demonstrations	Low	Highly regarded due to climate variability and change but too sophisticated for farmers to use outputs without experts' help.

Fertilizer and manure application rates	On-farm trials, pamphlets and field days	Average	Although yields increased, costs of optimal fertilizer rates are high for most farmers and most farmers do not have own enough cattle to enable them to apply optimal manure rates.
Soil amendments (liming)	Demonstrations and pamphlets	High	Farmers' soils were very acidic and lime improved yields greatly.
Hybrid seeds	Demonstrations, pamphlets and on-farm trials	Very high	Increased yields compared to retained open pollinated varieties (OPVs).
Drip irrigation	Look and learn tours and demonstrations	Low	Highly regarded but lack of funding by most farmers hampered adoption.
Tractors	Training, demonstrations and on-farm trials	Very low	Highly received (other farmers hire them occasionally) but very expensive for most farmers.
Livestock dehorning	Demonstrations	Average	Improved health of cattle and reduced injuries due to less fights.
Castration of bulls	Demonstrations	High	Less painful to cattle, easy to use.
Seasonal climate forecast (SCF)	Training by Meteorological Officers	High	Farmers depend on SCFs for crop management decisions; more so these days because of climate variability and change.

Notes: The adoption rate categories were estimated and agreed upon by respondents during FGDs. Very Low – less than 20 %; Low – from 20 % to 45 %; Average – 45 % up to 60 %; High – 60 % up to 80 %; Very High – 80 % up to 100 %. (Source: Extension agents' responses from SSIs and FGDs.

3.3. Strategies suggested by extension agents to encourage technology adoption

Extension agents perceived farmers to adopt less expensive, simpler technologies and those technologies they participated in developing as opposed to expensive, sophisticated technologies or those imposed on them by technology developers and extension agents. Further, respondents indicated that farmers will not consider adoption when they do not have adequate information including performance of technologies in their own farm conditions. Thus, respondents proposed that where possible technologies should be developed from farmers' own indigenous knowledge and practices. This entails that baseline surveys should be undertaken to determine their farming practices and problems. Additionally, farmers should be involved from the problem definition stage to the solution (technology) development stage.

Respondents also suggested that affording farmers ample time to learn new technologies, and the best way to support learning among farmers is by observing the effect of a technology on field operations and production. Thus participatory on-farm trials, demonstrations, shows, field days and look-and-learn tours should be utilized for farmers to see firsthand the tangible evidence of performances of technologies.

The presence of a willing and committed extension support system may result in improved adoption of recommended technologies. Such an extension system will provide farmers such information support to guide decision-making on technology adoption. Respondents highlighted a caveat to this extension system in the form of the need for extension agents to be technically competent to assist farmers where needed, as well as to link them with other key stakeholders. Respondents, thus, suggested that extension agents should be trained regularly and kept abreast of the latest technologies and market trends for them to offer services better and to offer them more confidently. They highlighted that sometimes farmers may consult them about certain technology with the hope of getting informed advice, but only to discover that the agents do not even know about the technology. In addition to regular training, respondents indicated that they need to be approachable, credible, and impartial for farmers to trust them and the technologies they disseminate.

Strengthening farmer-extension-research linkages was suggested as a way promoting learning from each partner's experiences and to find common ground on how to develop technologies tailor made for farmers' conditions. Respondents indicated that research and extension should build on successful indigenous technologies or innovations developed by farmers.

Despite the willingness of small-scale farmers to adopt modern technology, the cost of a technology presents one

of the major challenges. In this vein, respondents proposed the use of cheaper and locally available resources as a way of reducing the costs of developing technology and, hence, its price. This will make the technologies available to farmers at prices they can afford, thereby enhancing the chances of adoption.

Another suggestion was the availability of credit facilities at lower interest rates or with relaxed repayment conditions to enable farmers to adopt. Affordability of technology can also be achieved by downscaling certain technologies to level that can be utilized at the small-scale level. Respondents noted that downscaling of technology can also encourage adoption, as some technologies are just too bulky to be utilized on the generally small farm sizes that characterize small-scale farmers hence small-scale farmers do not even consider them.

IV. DISCUSSION

The majority of the respondents were in the middle age group of between 35 and 50 years old and they have more than 10 years extension work experience. These middle-aged extension agents tend to be mature and capable to handle the rigors of tedious extension work [1, 6]. The study also found that the minimum education level of respondents was the diploma level with a third attaining either a Bachelors or a Masters degree. This concurs with findings reported by [1, 6] who suggested that agricultural extension agents had the basic educational qualifications to perform their duties effectively.

The challenges confronting AGRITEX and its extension personnel are consistent with findings by [1, 4]. Similarly, [7] noted that the majority (78%) of Lesotho extension workers perceived lack of infrastructure, transport and facilities to be the main constraint to efficient extension delivery. These challenges result in reduced contact between farmers and agents. Without adequate contact there is little or no chance of farmers considering technology, much less adopting it. There is a positive correlation between technology adoption and farmer contact with extension agents [8]. However, [9] argued that accessibility of extension services alone is not enough, as extension agents should also have the resources and credibility to convince farmers, for without trust and credibility an agent's recommended technologies are easily dismissed.

AGRITEX has failed to offer induction courses and in-service training for many years due to lack of resources and this has affected the competences of their personnel [1]. Similarly, about 72.3% of extension agents in Imo State of Nigeria had not attended any in-service training since they were employed [6]. Extension workers perceive lack of appropriate in-service training as a major constraint in equipping them with the essential skills and competencies to adequately advise farmers [1, 7, 9].

The finding that extension personnel perceive the farmers to be very observant and innovative, especially when their livelihoods are at risk as highlighted by their resilient indigenous knowledge systems, is in total agreement and consistent with findings by [10 - 12]. As such, respondents valued farmer engagements in technology developments or testing technologies in farmer's own fields, as partners. This concurs with the argument by [1, 11] that farmers must be viewed by extension and researchers as equal partners, possessing different, but valuable experiences and skill sets to theirs. This entails iterative learning between farmers, extension agents and researchers [1, 13]. This iterative learning entails the need for extension to be flexible enough to determine and respond accordingly to the dynamics that surround farmers, their systems and their circumstances [1].

The pluralistic extension setup currently obtaining in Lower Gweru Communal area, where other actors like donors, research institutes and NGOs are "dictating" operations should not be seen as a negative by AGRITEX agents. In fact the setup should be embraced by extension agents where their role becomes more of facilitators or brokers. In these roles, extension agents assist in disseminating new technologies by acting both as a repository of information regarding technology experts and new technology opportunities and as a conduit between actors [14]. For extension agents to perform this role effectively, they need to possess good communication skills, ability to empathize, listen and value farmers and other actors' insights, impartial and technically competent [1, 4].

Further, the pluralistic extension setup has the potential to improve the farmers-extension-research/donor linkages which respondents suggested as a strategy to improve technology adoption by farmers. Furthermore, in such a setup most farmers feel encouraged to share their indigenous knowledge that maybe helpful to all partners including technology developers. Thus, engagement is the key; farmers genuinely engaged and working within their indigenous framework will create the demand [11]. Such an engagement may awaken farmers' interest to learn more about new technologies and participate in the testing them in their own fields before considering adoption.

Consistent with findings by [4] and [12], respondents perceived small-scale farmers to have developed successful innovations including seasonal climate forecasting, crop protection and soil and water conservation through their own indigenous knowledge,

practices and experiences. Conversely, the caveat issued by respondents regarding farmers' indigenous knowledge, that it is backward, conservative and can be an impediment to modern technology adoption, was also noted by [15]. Such thinking is the reason why farmers' indigenous knowledge have been ignored by most scientists and modern technology developers.

The major reasons for high adoption were simplicity of use, low cost of acquisition, improved production, and low risk of use. These findings concur with [4, 9, 16], who found that low cost technologies with high expected benefits, as well as short payback periods are more likely to be adopted. Conversely, low adoption rates were reported for bulky technologies (e.g. tractors) and expensive technologies including solar driers and metal silos and also for high-risk technologies such as bee farming [4].

The cost of a technology presents one of the major challenges to technology adoption by small scale farmers. This finding concurs with [4] and [9] who found the lack of capital and credit facilities to acquire and utilize technologies to be one of the critical reasons inhibiting adoption. Thus, making credit available at lower rates becomes particularly important where bulky technologies, which require high initial costs of setting up, are concerned. Such costs may be prohibitive to most small-scale farmers, but with affordable credit facilities, farmers may actually consider adoption. Similarly, technology developers should be encouraged to allow farmers to buy on hire-purchase or to acquire the technologies and pay later or to enter into contract farming.

The most preferred methods of disseminating technology used by respondents were observations, field days and demonstrations. The nature of learning (observation, discussions and sharing experiences) afforded in demonstrations, on-farm trials and field days are very powerful methods to use even with illiterate or less educated farmers [17]. Similarly, [11] and [13] proposed that effective learning in small-scale farming systems occurs when it is more interactive, experiential, field-based and participatory in nature. This nature of learning is beneficial to the development of farmers' decision-making, leadership, and management abilities [18].

Respondents also indicated that they use the farmer groups as entry points into a community for introducing new technology as they believe if the group adopts the technology, the members of the group then can spread the information and also encourage other farmers to consider adoption. This farmer to farmer extension within farmer groups is one of the most appropriate and effective modes of disseminating new innovations [7, 19].

Respondents highlighted that farmers often lack all the necessary information to make informed decision on technology adoption [11, 20]. Such information includes input and output markets, prices of products produced as result of using technology and how to utilize technologies properly [1, 4]. In addition to understanding the technical efficacy of the technology, [21] argues that the introduction any technology (or change to a farming system) should also be analyzed in terms of how it will affect the management, economic and sustainability aspects of the farming enterprise.

V. CONCLUSION

The perceptions of agricultural extension agents on the innovation and technology adoption processes/behaviors of small-scale farmers are of paramount importance in addressing poor and non-adoption of technologies. For one, extension agents play a pivotal role in fostering productive relationships between farmers and other key actors like scientists and technology developers. As shown in this study, extension agents are responsible for disseminating the majority of technologies in small-scale farming systems and have regular contact with farmers. This phenomenon makes them both a valuable source of information regarding the circumstances of small-scale farmers and potentially being part of the solution in enhancing farmer innovations (indigenous knowledge) and adoption of modern technology. As already shown in this study, extension agents suggested potential strategies aimed at addressing the poor technology adoption challenge. The potential of extension agents can actually be fulfilled by empowering them through regular in-service trainings about relevant up-to-date modern technologies so that they may be competent in offering farmers information support on how to utilize these technologies. Further, extension agents also need to be better resourced so as to be able to reach many farmers with technologies.

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Alarm: Mankind is Not Ready for Inevitable Global Climate Change

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"It is not the strongest and smartest who survive but the one who adjusts best to the changing environment."

Charles Darwin

Abstract— *This article is a scientific review, first, of the consequences of global warming and climate change, and second, of the urgent ways for humanity to adapt to these climate changes. It is shown that an increase in the concentration of CO_2 in the atmosphere, as well as an increase in its average temperature, correlates well with an increase in the number of natural disasters and, accordingly, an increase in budget costs for the removal of their consequences. On the other hand, the impossibility of completely stopping global climate change, let alone returning to its 1970 parameters, is discussed, for example: removing billions of tons of CO_2 from the Earth's atmosphere; restoring trillions of tons of ice at the poles of the Earth and its mountain peaks; reduce the acidity of the waters of the World Ocean and its cooling. Hence the conclusion is made about the inexpediency of spending hundreds of billions of dollars on "the fight against climate change" and the expediency of spending these billions on the urgent adaptation of mankind to an already changed climate. Further, the article examines in detail the ways and options to prevent the destruction and loss caused by hurricanes, flooding, wildfires, massive burning of fossil fuels, traditional agriculture, as well as huge pollution of the World Ocean: replacement of fossil fuels with green energy and green transport, the construction of only hurricane-resistant and fire-resistant buildings in hazardous areas, the construction of dams and powerful drainage systems in areas of probable flooding, the transition to superconducting underground electrical cables, the widespread use of small modular low-enriched uranium nuclear reactors, widespread use of heat pumps, the transition from traditional cattle breeding to artificial meat, the widespread in agriculture use of so-called vertical farms, minimization of food losses at all stages, and more. The main idea of this report was clearly expressed by Charles Darwin in his well-known quote: **"It is not the strongest and smartest who survive but the one who adjusts best to the changing environment."** That is, not the strongest nation (with the largest GDP), not the smartest nation (which will learn to extract all the excess CO_2 from the atmosphere), but the nation that is best adapted to live in this changed climate (with hurricanes, floods, droughts, wildfires, etc.) - will have more chances to survive.*

Keywords— ***global warming, climate change, natural disasters, urgent adaptation, environment***

I. INTRODUCTION

It is already clear for any sensible person that climate change on the Earth has led to a sharp increase in hurricanes, floods, wildfires, droughts and other natural disasters and to a huge increase in financial damage to federal and local budgets [1].

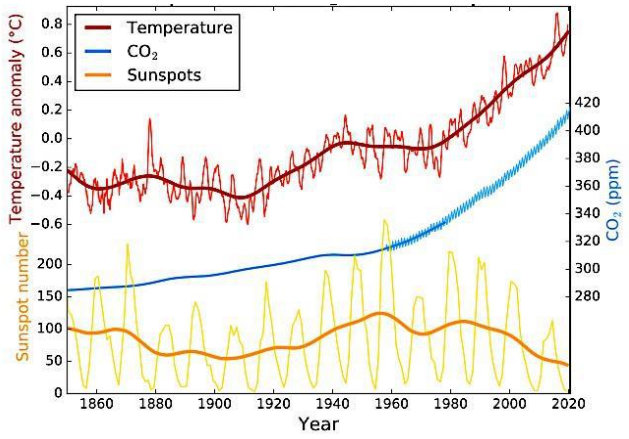

Fig. 1. Change in the average temperature of the Earth's surface (red line), CO_2 concentration in the atmosphere (blue line) and solar activity (yellow line) for 1860 - 2020 [2]

As Fig. 1 shows, the turning point (accelerated growth) in CO_2 concentration and temperature of the atmosphere came approximately 1960-1970.

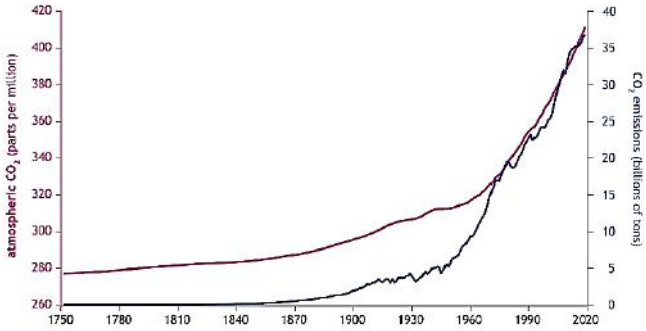

Fig. 2. Correlation between the growth of CO_2 emissions by industry and its accumulation in the Earth's atmosphere [3]

As Fig. 2 shows, the turning point (accelerate) in the growth of CO_2 emissions by industry and its accumulation in the Earth's atmosphere also came approximately 1960-1970.

Fig. 3. Trend in the number of natural disasters, 1900-2020 [4]

As Fig. 3 shows, the number of natural disasters is also increasing markedly around 1960-1970. Thus, as Figs. 1, 2, and 3 show, the turning points (accelerated growth) match for three graphs and came approximately 1960-1970 when the intensive consumption of fossil fuels by industry and transport began.

However, the most important (and most alarming) conclusion for scientists was not the fact of "global warming" itself but the fact that the Earth's climate is capable of changing much faster and more radically than we thought before, and humanity has no time to adapt to these climate changes either technologically, or evolutionary. In addition, some of the changes that have already occurred (an increasing concentration of CO_2 in the Earth's atmosphere, acidification of the World Ocean with excess CO_2, melting of Arctic/Antarctic ice) are irreversible. For example, a 2019 NASA report, indicated that approximately 10 gigatons of CO2 would need to be removed from the atmosphere each year until 2050 to limit global warming to 1.5°C (2.7°F), that is the goal of the Paris Climate Agreement 2015 [5]. In additional, since 1994 up to 2020, satellite imagery has revealed over 28 trillion tons of ice have melted in Greenland and Antarctica, as well as the Arctic and Southern Oceans [6].

In my opinion, this is really impossible, and this is a senseless waste of huge efforts and huge money. I am sure that the hundreds of billions of dollars allocated in the world for "the fight against global warming" are much more meaningful and important to spend on the adaptation of humankind to new climatic conditions. Remember the well-known proverb, ***"If the Great Flood is inevitable, one must spend the remaining time learning to live underwater."***

II. HURRICANES AND FLOODING

Here are some facts:

The monstrous hurricane Katrina literally destroyed New Orleans (Louisiana, USA) in 2005. Approximately 80% of the city area was under water, 1836 inhabitants died, approximately 700,000 people lost their homes, and economic losses reached $125 billion [7].

Floods in Thailand in 2011: a total of 65 of Thailand's 76 provinces were affected, 616 people died, more than 1.3 million people sought medical help, and 9.5 million people were left homeless. The total damage is estimated at $16 billion [8].

In July 2021, the state of Maharashtra and neighboring states of India received the heaviest rains in the last 40 years. In some parts of the state, up to 600 mm of precipitation fell per day. The flood caused landslides in various parts of the

state. The total number of flood victims reached 213 people. Approximately 230 thousand people were evacuated [9].

In September 2022, hurricane Ian attacked the state of Florida (USA): 81 people died, hundreds of houses were destroyed, more than 2.6 million Florida residents were left without electricity, and damage was estimated at 40 billion USD [10].

Monsoonal downpours in Pakistan in autumn 2022 triggered floods and landslides that destroyed homes and infrastructure and claimed over 1,300 lives. According to the UN, the elements left tens of millions of people without a roof over their heads. A third of the country's territory is flooded, and crops and livestock are destroyed [11].

As seen from the above information, humanity around the world is constantly faced with the same consequences of hurricanes and floods:

A) The destruction of thousands of homes, especially 1-2-story private residential buildings;

B) Flooding of vast territories;

C) Mass de-energization of territories attacked by a hurricane;

D) These three factors lead to the death of people there.

Thus, the engineering solutions to prevent these tragic situations are quite obvious, and these solutions have nothing to do with the ineffective "fight against global warming."

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2.1. The destruction of thousands of homes

It is necessary to allow the construction of only "hurricane-resistant" residential and public buildings in any hurricane-prone areas. This is especially true for 1-2-story residential houses. It should be monolithic concrete or foam concrete, and even better - reinforced concrete; load-bearing columns must be firmly fixed in the ground (Fig. 4) – [12].

Fig. 4. Fill the frame monolithic reinforced concrete buildings, including 1-2-story residential buildings

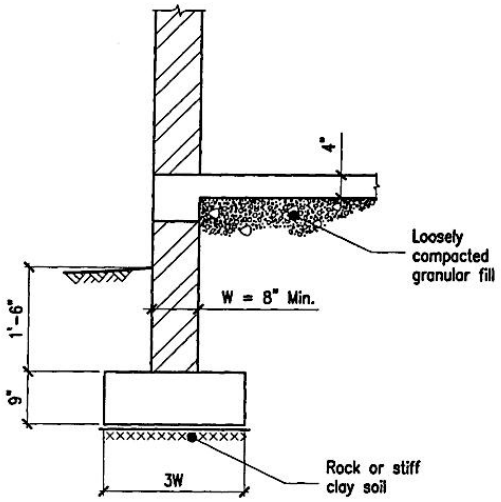

Fig. 5. Permissible arrangement of footing

All exterior walls and interior load-bearing walls should be supported on reinforced concrete strip footings. Interior walls may be supported by thickening the slab under the wall and suitably reinforcing it (Fig. 5). The foundations should generally be located on a layer of soil or rock with good bearing characteristics. In addition, 1-2-3-story residential buildings can be "printed" on giant 3D printers, as startups Shanghai “WinSun” or California's “Icon” do. 3D-printing a three-bedroom home can be fulfilled in 24 hours versus four weeks for typical the same building.

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2.2. Flooding of vast territories

It is necessary in every hurricane- and flood-hazardous region of the world to carry out hydraulic engineering

design of the necessary dams, as well as large drainage systems and then build them at any cost.

For example, flood control in the Netherlands began with the arrival of man in these places and continues to this day. The Zuiderzeewerken project included a dam system as well as land reclamation and drainage works. One of the main tasks of the project was the construction of a dam enclosing the large shallow bay Zuiderzee from the North Sea. For this, the Afsluitdijk dam was built, 30 km long, 90 m wide, and 7.25 m high above sea level. In the 1953 flood, Afsluitdijk dam paid for itself overnight, preventing dangerously high water from invasion of the central regions of the Netherlands [13].

Drainage systems for regions that are regularly flooded are also (such as dams) grandiose projects. One of the best, most efficient, and most impressive in the world is Tokyo's drainage system. The Tokyo Drainage System (TDS) [14] is one of the largest and most advanced in the world. It is located 15 km from Tokyo. It is designed to drain water during heavy rains and floods (the average rainfall in Tokyo in the rainiest October is 200 mm; the annual rainfall in Tokyo is 1520 mm).

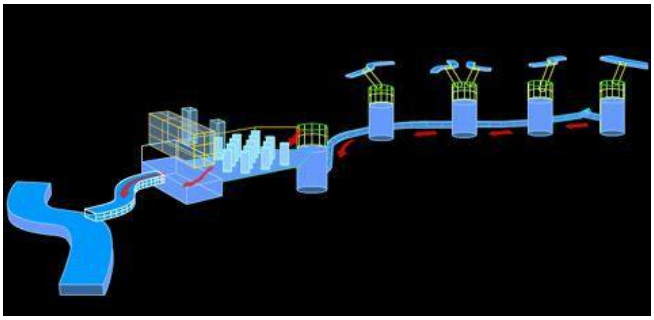

Fig. 6. Scheme of the Tokyo drainage system (TDS)

(on the right - 5 wells, on the left side - a river)

It has 5 huge wells every 1 km, each 70 m in height and 30 m in diameter. Wells connected with each other by large pipes (Fig. 6). The pipe diameter is 10 m, and all wells are connected by the same pipes to the Edogawa River (through a concrete dam).

Fig. 7. "Water pressure control bath" (size 178x77x18 meters)

The main underground hall of the TDS "Bath for Regulation Water Pressure" (it is sealed) has a size of 178x77 meters and a height of 18 m, and the vault is supported by 59 reinforced concrete columns (Fig. 7). The TDS gas turbine pumps (located in a separate fortified sealed bunker) are capable of pumping 200 m^3/sec of storm water (that is, "1 standard swimming pool per second"). Everything is automated and computerized. After the launch of the TDS, the average level on Tokyo's streets of water decreased 10 times. The total area of the system is 6.5 km^2. TDS had been under construction for 8 years - from 1992 to 1999. Project cost - 2 billion dollars.

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2.3. Mass de-energization of territories attacked by a hurricane.

Electrical power cables in all hurricane hazardous (as well as fire hazardous) areas should be laid exclusively underground through cryogenic superconducting underground cables in watertight and heat-resistant shells. Electrical power cables are built above the ground on metallic and even wood pillars; therefore every hurricane or forest fire leaves millions of people without electrical power. (In addition, worn high-voltage power lines are often themselves responsible for forest fires. For example, California-based Pacific Gas and Electric (PG & E) was found to be guilty for so-called Camp fires (California, 2018).

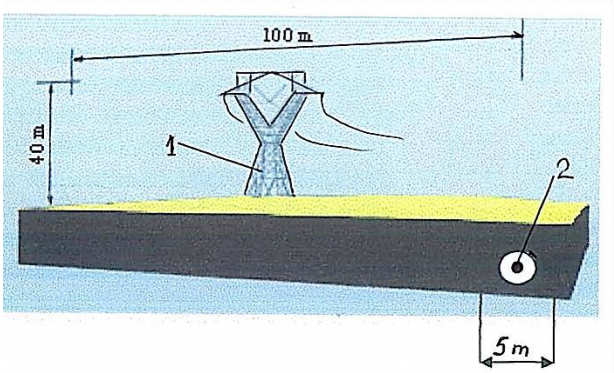

Fig.8 . Comparison of conventional high voltage line (1) and cryogenic superconducting cable (2) (https://www.amsc.com)

American Superconductor Corporation manufactures cryogenic superconducting cables for high voltage and high current electrical networks. This is a thin copper cable in an empty pipe of small diameter filled with liquid nitrogen. From above, the pipe (with a cable inside) is reliably covered with hydro- and thermal insulation. The use of such cables for high power networks (5 GW or more) over long distances (1-2 thousand km or more) can bring many benefits. First, the efficiency of power transmission over a superconducting cable is almost 100% (i.e. almost no losses; losses in conventional high-voltage networks - up to 10%). Second, a single superconducting cable for a 5 GW line will be ten times thinner than a normal copper cable. Third, a cryogenic cable can be laid underground with a "safety zone" of 5-10 m, while a conventional transmission line of the same power requires a right-of-way 100-200 m wide, and hundreds of metal poles 30-50 m wide (see Fig. 8). Fourth, I emphasize again that hurricanes, floods, and fires will not damage such an underground cable.

III. WILDFIRES

Wildfires are a huge disaster for our planet: humanitarian (death of people and animals), environmental, economic. In addition, forests are an important climate solution, absorbing carbon dioxide equivalent to more than 10% of annual greenhouse gas emissions.

In the summer of 2017, more than 120,000 hectares of forest burned out in California, more than 70 people died, approximately 20,000 houses burned down, and the total damage exceeded $20 billion. Between 2021 and 2022, wildfires accounted for over $11.2 billion in damage across the United States [15].

As a result of wildfire in Australia in 2019 (8 million hectares of forests), at least 3 billion animals were affected. More than 60 thousand koalas, more than a million wombats, and several million kangaroos died; additionally, more than 143 million mammals, 2.5 billion reptiles, 180 million birds and 50 million frogs died in the fire [16].

From each hectare of forest fire, up to 100 tons of soot particles and up to 10 tons of toxic fire gases are emitted into the atmosphere [17].

The Dixie Fire in California (2021) was the largest wildfire in the history of the state, covering over 195,000 hectares. Pacific Gas & Electric told authorities that the fire may have started due to a short circuit when a burning tree fell on high-voltage wires.

Additionally, according to the data of the EU Joint Research, Europe in 2022 is experiencing the worst drought in 500 years. The drought caused forest fires and severely reduced crop yields.

How can wildfires be prevented and suppressed?

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3.1. Clean out the old forest and restoring burnt forests

For example, the U.S. The government explained that the nation's well-intentioned forest strategy over the past century has created an unnatural buildup of materials that act as kindling for wildfires. We urgently need around the world to start utilizing everything in the forests that kindle: dried twigs, dead trees, grasses, shrubs, and even old houses. For example, the area of such forests in the United States (California, Colorado, Oregon, other states) is approximately 50 million acres and will require approximately 50 billion dollars for 10 years [18]. Additionally, the US government has committed to helping deliver global goals to end natural forest loss by 2030 while restoring at least an additional 200 million hectares of forests to plant an estimated 1.2 billion trees that will sequester 75 million metric tons of carbon [18].

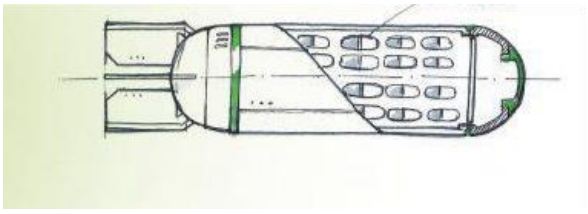

Fig. 9. "Seed bomb" (inside container are capsules with tree seeds)

It is interesting that "Lockheed Martin Corp." proposed creating new forests and restoring burned-out forests using "seed bombs" (Fig. 9). It can be done using the military airplanes C-130 (also known as the "Hercules") for mass planting trees by bombing. The possibilities are amazing. They can fly on 1,000 ft at 120 knots, planting more than

3,000 capsules a minute across the landscape and each capsule contains a sapling.

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3.2. Extinguishing of wildfires

The process of extinguishing the flame has a “threshold” character, i.e. for that, it is necessary to have a strictly 100% required amount of the firefighting agent for quite a long time simultaneously in any area of fire (including burning forest) that we extinguish [19]. Otherwise (in case of insufficient quantities of extinguishing agent or during pauses with its delivery), the fire will not subside but will flare up again and again and spread quickly.

The norm for extinguishing burning firewood is 0.3 kg/m^3 of flame (it could be ammonium phosphate). However, these 0.3 kg should be in EVERY m^3 of burning wood CONTINUOUSLY for at least 30 minutes [19]. The precipitation velocities calculated from the well-known Stokes law for single particles (ammonium phosphate) of 100, 50, and 5 micron diameter are 63, 15, and 0,3 cm/s, respectively. However, the precipitation of an aerosol cloud of the firefighting powder inside a turbulent flame is a much more complex process.

Therefore, for example, California (and all other fire-hazard regions of the world) should be sufficiently completed by aircrafts and helicopters with large load capacity for firefighting. The problem is that the ALL area of the fire must be COMPLETELY covered by a fire extinguishing agent (powder, foam, water). To do this, it needs to have a big squadron of fire planes (several tens), so that when the last plane will drop the fire extinguishing agent on the flame, the first one would have time to recharge and to arrive at the fire. They need a nonstop “aviation fire extinguishing carousel" over the wildfire!

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3.3. Fire resistant houses

As in the case of hurricane-prone areas, similar recommendations apply for fire-prone areas: it is necessary to allow the construction of only "fire-resistant" residential and public buildings in any fire-prone areas. This is especially true for 1-2-story residential houses. It should be monolithic concrete (see Fig. 4). However, in this case, it will be the so-called refractory or heat-resistant concrete. Saunas and fireplaces are usually made from such concrete for ordinary housing. Additionally, for fire-hazardous regions, additional processing of the outer layer of concrete with special heat-resistant coatings is necessary. For example, researchers at the Nanyang Technological University (NTU) in Singapore have invented an invisible coating that can be applied to wood to make it fireproof. The coating is transparent and just 0.1 mm thick, and it is invisible to the naked eye. When exposed to fire, the coating becomes a char that is more than 30 times its original thickness [20].

Since forest fires completely destroy electrical networks, for fire-prone regions electrical power cables should be laid exclusively underground through cryogenic superconducting underground cables (see Fig. 8).

IV. GREEN ENERGY

4.1. Sunlight and Wind

The average flow of solar energy reaching the Earth's surface is 200-250 W/sq.m, while human economic activity requires only 15-20 W/sq. m. for highly industrialized countries and no more than 3 W/sq. m for poor countries. That is, theoretically, it is enough to use up to 8-10% of solar energy to fully meet the energy needs of mankind without using of fossil fuels at all.

After 2040 (via 20 years only!) solar, wind and hydrogen energy will almost completely replace coal and oil and partly replace gas. According to UN Environment Program (UNEP) data, by 2025, 1 "green kWh” of energy will cost as much as 1 "coal kWh”. Electric cars will be on the roads (by 2040, 90% of all sold motor cars in the world will be electrical). Aircraft will also fly through electrical energy. In the total energy balance of world electricity production for 2021 (28,500 terawatt-hours), the share of solar and wind generation exceeded 10% for the first time. The introduction of generation based on renewable energy sources (RES) in the world by 2030-2035. will reach a record level: 740 GW will be introduced in the EU, and the US will be able to provide up to 40% of the country's electricity (approximately 1500 GW); also, over the next 10 years, offshore wind energy in the world will “add” more than 200 GW [21].

The main advantage of green energy (sunlight, wind, water flow) over fossil fuels (coal, oil, and natural gas) is not only curbing climate change. When comparing the price of "green" and "fossil" kilowatt, economists usually don’t take into account that green energy sources (unlike fossil fuels) don’t need to be sought (by geologists), mined, transported to a power plant in order to incinerate in furnace of steam boiler ("green energy" can be supplied directly to consumers.)

That is, in replacing fossil fuels with green energy (sunlight plus wind), humanity is moving on the right track, and moving quickly and confidently.

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4.2. Small hydropower stations

"Small hydropower station" (SHPS) uses the energy of the flow of rivers (the capacity of such flow SHPS does not exceed 30 MW), as well as the energy of ocean and sea tides (the capacity of such tidal SHPS does not exceed 300 MW). For comparison, the world's largest hydroelectric power plant, the "Three Gorges" (China), has a capacity of 22,500 MW. But for this, the huge Yangtze River was completely blocked by a dam in which 65 million tons of concrete were laid (*https://www.britannica.com/topic/Three-Gorges-Dam*). For example, in France, the total capacity of the all SHPS is approximately 2000 MW but this is less than 2% of the total electricity generated in France. However, the average cost of 1 kW/h of such hydroelectric power is only $0.05 but the price of a typical 1 kW/h is $0.15, three times higher.

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4.3. Ecological nuclear power

Nuclear power is neither strictly renewable nor fully green for well-known reasons. Natural uranium contains 99.3% 238U and only 0.7% 235U. However, only the 235U isotope is suitable as fuel for conventional nuclear reactors. Therefore, natural uranium has to be enriched - it is expensive and dangerous as dangerous traditional nuclear power stations in general. The main ways to "more green" future nuclear technologies are as follows:

1) Stop using enriched uranium-238 as fuel, switch to unenriched (or depleted) uranium, and even better, safe thorium;

2) Switch to nuclear technologies based on fast neutrons, while using unenriched uranium, as well as afterburning highly radioactive waste to their minimum radioactivity in breeder reactors;

3) Switch to the production of small modular nuclear reactors (SMNRs) with a capacity of up to 300 MW. SMNRs can also be used in conjunction with renewable energy sources to improve their efficiency in hybrid cogeneration.

As a result of using the mentioned technologies, not only will it be possible to save up to 25% of natural uranium reserves, but the average burnup of nuclear fuel will become several times greater. Additionally, the accumulation of dangerous isotopes of trans-uranium elements in its slag will be several thousand times less.

Fig. 10. Hyperion Power Module

(its size is comparable to the size of an elephant)

A series of small modular nuclear reactors (SMNRs) is now being created on the basis of the mentioned technologies. For example, Hyperion Power Generation Company (USA) has developed a compact Hyperion Power Module (capacity 25 MW) (Fig. 10). In addition, Terrapower (USA) has created a traveling wave reactor (TWR) that uses depleted uranium and is able to operate for 100 years without fuel refueling. A similar, but ultra-compact 4S reactor (10 MW) has already been developed by Toshiba (Japan), whose operation life is 30 years without fuel refueling.

In addition, the US Department of Energy recently selected 5 small modular nuclear reactors (SMNRs) to receive government support:

• BWXT's Advanced Nuclear Reactor, a mobile microreactor using TRISO fuel for use in remote areas with no centralized power grid (TRISO is the most efficient and safest nuclear fuel in the world);

• Westinghouse eVinci microreactor, also using TRISO fuel;

• Hermes reactor - a smaller version of the high-temperature Kairos Power reactor using molten fluoride as a coolant (KP-FHR);

• Pressurized water reactor SMR-160 developed by Holtec;

• Molten salt (molten chloride) reactor developed by Southern Company Services Inc.

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4.4. Heating houses using heat pumps

Unfortunately, human civilization has gone on a dangerous and inefficient way of energy production by incinerating fossil fuels (coal, gas, and oil). However, I would like to pay attention to the fact that the nature has created other grandiose thermal energy source for mankind - it is so-called "secondary" solar energy (i.e. utilization of heat of the upper layers of oceans, seas, rivers, and ground and the lower layer of the atmosphere). This "secondary"

solar energy can be utilized with the help of so-called heat pumps (Fig. 11).

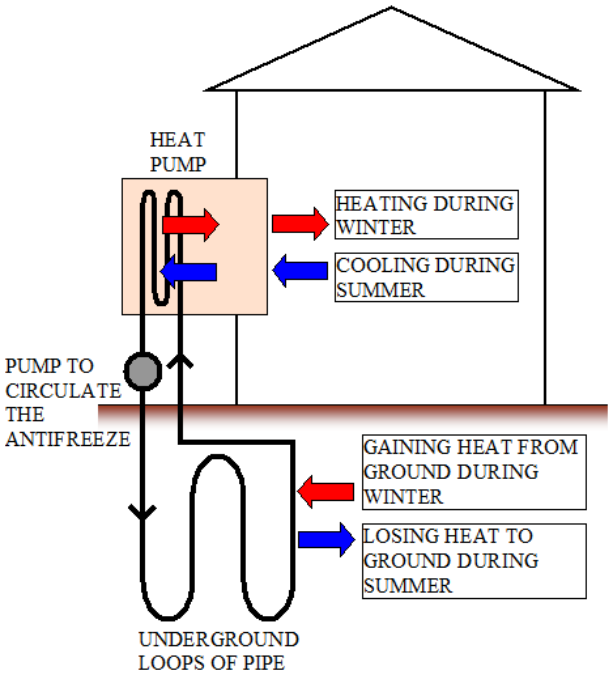

Fig. 11. Schematic diagram of a heat pump type "ground-air" (by Zach Smith)

The heat pump works like a "refrigerator in reverse" - the interior heats up, and the environment (a section of a river, ground or surrounding atmosphere) cools. The heat carrier here is liquid ammonia (-40 °C). Therefore, if a coil with liquid ammonia is immersed in a river (lake) or buried in the ground, then even in winter (-5 °C), this water or ground will be "hot" for liquid ammonia, and it will evaporate and will perform work, and water (ground) around the coil - will be cooled.

Depending on the type of heat pump (ground-to-air, water-to-water, etc.), the theoretical efficiency of heat pumps can reach 80% (Fig. 12).

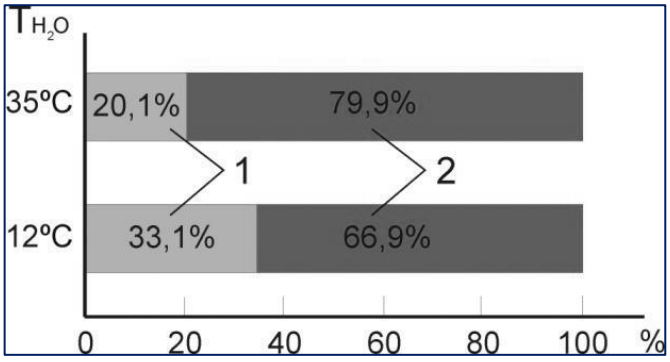

Fig. 12. Heat-pump maximum efficiency:

1 -energy spent for work of the heat-pump; 2 - energy received from work of a heat pump (especially if to combine a heat pump with solar panels on the house roof)

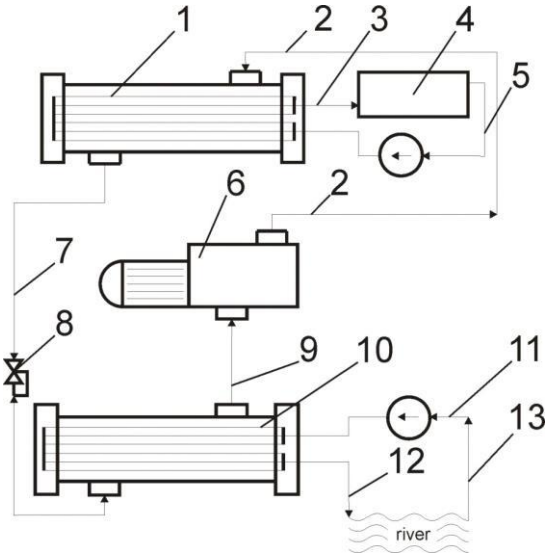

Fig. 13. The scheme of a "non-fuel" power station (NFPS) (Krasnyansky's project):

1 - condenser; 2 - compressing of the more hot gasiform-ammonia (+80 ºC); 3 - more hot water (+70 ºC); 4 - heat-exchanger, combined with the Stirling-engine and the electric-generator; 5 - less hot water (+30 ºC); 6 - compressor; 7 - compressing of the less hot gasiform - ammonia (+30 ºC); 8 - choke; 9 - fluid-ammonia (-40 ºC); 10 - evaporator; 11 – water pump; 12 - more cold water (+ 5 ºC) into river; 13 - less cold water (+ 10 ºC) from river.

However, in countries with a hot climate there is no need for space heating and use of heat pumps for this. However, at the same time, the heat pumps can be turned into a source of electricity (especially given huge excess heat in such countries). If we combine in a united cycle a heat-pump, the Stirling engine (this is an "external combustion" engine), and a heat-exchanger (Figs. 13 and 13a) - we shall have so-called "non-fuel power station" (NFPS) where transformation of heat into useful mechanical work and further into electricity will occur with high efficiency.

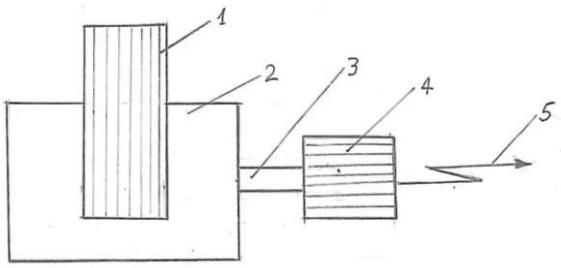

Fig. 13a. Position 4 of the Fig. 13 (in detail)

1 - external combustion chamber of the Stirling-engine (it is

engine of external combustion); 2 – heat-exchanger of the NFPS; 3 – shaft of the Stirling-engine; 4 - generator of an electric current; 5 – electric current for consumers.

Herewith:

a) the cost of heating a home/office will be decreased;

b) the use of fossil fuels will decrease;

c) the negative change of a climate will be decreased (because you will pump out superfluous heat from the environment).

For example, for present German consumers, the cost for the electricity needed to power a heat pump is approximately 35% cheaper than natural gas, according to the German company Verivox. However, the high purchase and installation price (approximately 30,000 euros) of the heat pump can run up to three times that of a conventional gas furnace *(NYT, Dec. 5, 2022.)*

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4.5. Zero-Energy Houses

In the last decade, the world has become popular with so-called “zero-energy houses”, i.e. buildings that are highly energy efficient, able to independently generate and save energy and consume it from their own sources all the time [22]. Such buildings are now being intensively built around the world: FKI Tower and "Dancing Dragons", (Seoul, South Korea), Hikari Lyon (France), New-Blauhaus (Mönchengladbach, Germany), Manitoba Hydro Place (Winnipeg, Canada), Clean Technology Tower (Chicago, USA), and others. In additional, China built a 300-meter 70-story "Pearl River Tower" in the city of Guangzhou. It's a skyscraper with "zero energy"(Fig. 14).

That is, it will not consume electricity from the external network, and will also consume almost no water. The house will use wind and solar energy. The curved facades of the Tower are designed to direct the wind into special "vents blown through" that are on each of the floors and where wind turbines are installed. Along the façade, there are rows of solar panels (photovoltaic panels) that supply electricity to the home's batteries. In addition, solar thermal collectors are installed on the building, which heat water for the inhabitants of the skyscraper. The project includes a rainwater collection system, as well as a wastewater treatment and recycling system, which should minimize the house's need for an external water source.

Fig. 14. Zero-energy skyscraper «Pearl River Tower» [23]

(spiral "wind vents" are visible on the right side of the house, solar panels are on the facade)

The author of this article proposed his own project "Zero Energy House" adapted to the technological capabilities of the so-called "developing countries" (Fig. 15).

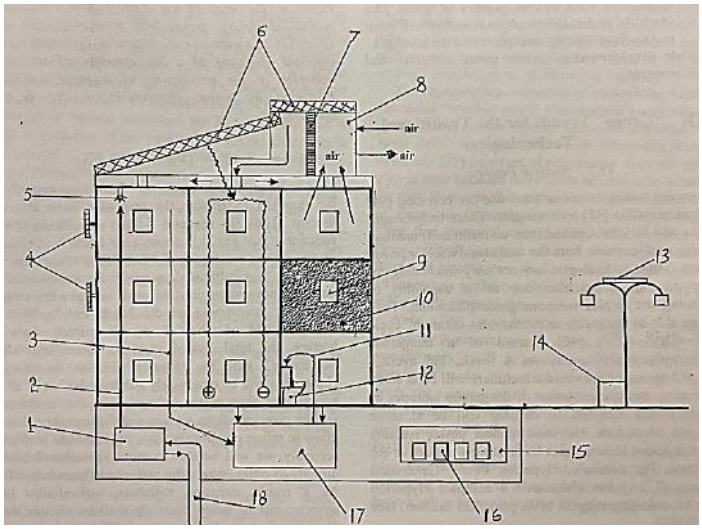

Fig. 15. Zero Energy House (Krasnyansky’s project):

1 – heat-pump; 2 – warm water; 3 – cool water; 4 – micro-wind-turbines; 5 – light-emitting diode; 6 – solar panel; 7 – air filter; 8 – air-exchanger; 9 – "photovoltaic windows" that serve as an additional electricity generators; 10 – super-insulation; 11 – water after cleaning; 12 – toilet; 13 – solar panel; 14 – electrical accumulator; (13 and 14 – are a street lamp post with independent generation of the electric power); 15 – laundry; 16 – “dry” washing-machines (without using of water and any detergent); 17 –

bio-chemical cleaning of the sewage; 18 – coil with liquid ammonia.

In addition, the British company "iHelios" produces electric infrared "wallpaper" that can heat a residential or office space. In fact, these are the thinnest metal sheets hidden behind plaster walls or real wallpaper and connected to the electrical network.

V. GREEN TRANSPORTATION

Currently, more than one billion internal combustion engines are in operation worldwide (cars and trucks, diesel locomotives, tractors, agricultural and construction equipment, armored vehicles, airliners, etc.), which annually burn approximately one and a half billion tons of motor fuel (gasoline, diesel fuel, jet fuel), and they pollute the atmosphere with toxic and greenhouse gases.

The efficiency of an internal combustion engine is low - at best 30%, on average 25% (see Fig. 16).

Volkswagen *(https://www.volkswagen-newsroom.com/en)* gave interesting statistics for Europe: the average speed of urban transport in the majority is 22 km/h; however, with such meager indicators, these cars consume an average of [10 (cars) -15 (pickup trucks, minibuses) - 25 (buses)] liters of motor fuel per 100 km. Most of this fuel is burned at traffic lights or traffic jams; for small trucks - also for small loading and unloading; in the case of passenger transport - at stops with the engine running.

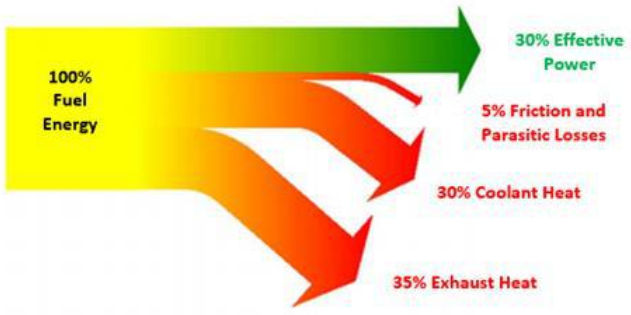

Fig. 16. Gasoline engine efficiency diagram ("Triple A" image)

Therefore, the US, EU, China, and Japan have already committed themselves to completely stop the production of gasoline and diesel cars by 2040 and switch to electric vehicles. Urban and intercity transport also needs to be converted to electricity, or at least replaced with "hybrids", so that at traffic lights, in traffic jams or at stops, it does not waste fuel in vain, but charges its battery.

In addition, a dense network of high-speed (200-300 km/h) electric railways for public transportation (electric trains, subway, etc.) is also an effective way to reduce the consumption of petroleum products (after all, electricity can be obtained without using fossil fuels). China is the "champion" of this kind of transport: their length is 35,000 km, followed by Germany - 3,600 km. For example, the total length of the French Train à Grande Vitesse (TVG) is 1700 km with 149 stations. It carries approximately 40,000 passengers per day (about 12 million per year) at a speed of 320 km/h. If these passengers used private cars, they would use up annual 100,000 tons of gasoline (*https://en.wikipedia.org/wiki/TGV*).

Alice, an electric aircraft developed by Israeli startup Eviation *(https://www.eviation.com)*, flew to 3,500 feet and stayed in the air for 8 minutes. Alice is a nine-seat regional aircraft for two crew members and nine passengers with a range of up to 830 km and a speed of up to 460 km/h; load capacity 1.1 tons.

That is, in replacing traditional gasoline and diesel vehicles with electric vehicles, humanity is also moving on the right track but is not moving fast enough.

VI. ALTERNATIVE AGRICULTURE

Agriculture is one of the most powerful sources of greenhouse gases. When sowing, harvesting, and transporting agricultural products around the world, millions of tons of gasoline and diesel fuel are burned. Cattle breeding creates additional problems. Here, there is a low efficiency of the conversion of vegetable proteins into animal one. Therefore, it is necessary to grow approximately 8-10 kg of vegetable protein in the form of forage for cattle to produce 1 kg of animal protein in the form of, for example, beef; that is, the energy efficiency of this process is only 10-15%. Additionally, animal husbandry requires 4-5 times more water than forage production: 15,000 liters of fresh water are needed to produce 1 kg of beef, and only 4,000 liters are needed to produce 1 kg of beans. In addition, a typical cow "produces" and releases 400-500 liters of the greenhouse gas methane (which is a side effect of its digestive processes) into the atmosphere per day, and there are approximately 1.5 billion cows in the world. I.e. cows are responsible for 10% of total greenhouse gas emissions [24]. Vegetable protein (which contains all eight "essential" amino acids) is significantly superior to cattle meat in all medical, environmental and economic indicators.

The way out for humanity is, first, a complete rejection of cattle breeding (with the preservation of much more environmentally friendly poultry farming) and the transition to "artificial meat" and "artificial milk"; second, partial

transfer of crop cultivation to large cities with help of the so-called "vertical farms".

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6.1. Artificial meat (cultured meat, grown meat)

The process of producing artificial meat involves obtaining stem cells from animal muscles and using a special protein that allows the cells to grow into larger pieces of meat [25, 26]. An artificial "meat plant" requires much less land (only 1% of the land compared to a conventional farm of the same meat productivity). In addition, under sterile artificial conditions, you can obtain an environmentally friendly product without any toxic metals, worms, giardia and other "troubles" that are often present in raw meat. Additionally, artificially grown meat does not violate moral standards: there will be no need to raise livestock, and then ruthlessly kill them. Growing meat in vitro requires five times less energy and 10 times less water than conventional production of the same amount of beef and reduces greenhouse gas emissions by 20 times compared to raising livestock for slaughter. Microsoft founder Bill Gates, Google co-founder Sergey Brin, and famous actor Leonardo DiCaprio invested in the development of artificial meat.

The Good Meat company [27] plans to start building the complex of the world's largest bioreactors for the production of artificial meat. Commissioning of the equipment is scheduled for the end of 2024. The company plans to grow artificial beef and chicken.

There is also vegetable (vegan) meat (it is made from vegetable protein - pea, bean, and vegetable oil (usually rapeseed). Such "meat" is manufactured and sold by Beyond Meat Corp. *(https://www.beyondmeat.com/en-US/).*

Perfect Day *(https://perfectday.com)*, a Silicon Valley startup, has developed "artificial milk" technology. Perfect Day uses a completely new technology: its "milk" is produced by yeast. To do this, nutritional yeast DNA was genetically modified so that the microorganisms produced milk proteins, including casein, lactoglobulin and lactalbumin. The company believes that its technology could become the basis for creating imitations of many dairy products, from cheeses to yogurts.

The American startup Brown Foods *(https://www.ycombinator.com/companies/brown-foods)* introduced artificial milk made using cell culture technology. The founders of the startup claim that the resulting product is similar in properties and texture to cow's milk. The startup slogan is *"Making real milk without any cows!"*

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6.2. Vertical farms

A vertical farm is a highly automated agriculture-industrial complex for growing crop plants using hydroponics or aeroponics methods indoors inside a specially designed building. The main differences between vertical farms and traditional greenhouse farms are multitiered plantings (Fig. 17) and a fully controlled indoor climate. The modern use of multilevel racks in combination with LED-based phyto-lighting, irrigation and fertilizer automation allows vertical farms to increase yields per unit area by 5 or more times compared to traditional farming methods. It is noted that production on a vertical farm is approximately ten times more efficient than in greenhouses and a hundred times more efficient than in an open field [28].

Fig. 17. Vertical farming with hydroponics (for each farm floor) (by Amy Wilson, MSc)

Vertical farm projects have the following benefits [29]:

• crop stability, which does not depend on natural conditions;

• application of water collection and purification systems that reduce water consumption by 95% compared to traditional agricultural production;

• closed ventilation cycle, purification and ionization of air in the growing rooms, which makes it possible to exclude the occurrence of pests and phyto-pathologies, as well as the use of pesticides, herbicides and insecticides;

• possibility of location within city limits, in particular, in repurposed industrial infrastructure facilities, which reduces transportation costs and transportation losses by dozens of times;

• energy independence (when using solar and wind energy).

In addition, vertical farms are a faster and more efficient response to severe droughts than long-term breeding of drought-tolerant agricultural plants.

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6.3. Losses in food chains

According to the World Health Organization, in 2020, out of 7.5 billion people living on the planet, approximately 800 million people were partially or completely hungry. The world annually produces approximately 4 billion tons of food, and this could be enough for all the inhabitants of the planet if food was rationally used and distributed.

Food disappears at all stages of production - during collection, processing, storage, transportation to retail chains and food outlets [30].

Globally, approximately 14% of food produced is lost between harvest and retail, while an estimated 17 percent of total global food production is wasted (11% in households, 5% in food services and 2% in retail) [31]. However, in the so-called developed countries, this figure is even higher; for example, in the United States, approximately 30% of food is thrown away (on average, an American family of four throws $2,000 worth of food every year) [32]. At the same time, it must be emphasized that we are not talking about food waste but about food products suitable for consumption. Thus, we are not talking about, for example, potato peels, but about unused, usable potatoes, which became "food waste" only after they were thrown into the trash can.

The result is that unused food consumes approximately a quarter of all freshwater consumed, as well as 300 million barrels of oil per year.

Thus, measures to prevent large crop losses, and especially extensive measures to prevent usable food from being wasted, will not only help overcome hunger on the planet but also prevent the useless burning of millions of tons of oil products, which will significantly reduce the emission of greenhouse CO_2 into the atmosphere.

VII. THE SICK WORLD OCEAN

The World Ocean is a great helper of humankind in adapting to climate change. UNESCO Director-General Audrey Azoulay said: "The ocean is the heart of our planet. Humanity cannot live healthy if our oceans are sick."

The world's oceans absorb more than 90% of the excess atmospheric heat and approximately one-third of the carbon dioxide emitted by industry and transport. As the analysis showed, for the entire period of observations (1955-2020), the thermal energy stored in the waters of the world ocean increased by 380 zettajoules (zetta is 10^{21}). More than half of this heat is concentrated in the upper layers of the ocean (at a depth of up to 200 m). Warmer oceans contribute to severe storms and hurricanes and increase the risk of flooding [33].

Additionally, due to the greatly increased content of CO_2 in the atmosphere (and, consequently, its high partial pressure), the world ocean absorbs an increased amount of CO_2. Therefore, for 13 years (from 1994 to 2007), the world ocean "removed" 34 billion tons of CO_2 from the atmosphere, which is approximately 30% of the total global CO_2 emissions for this period [34]. Scientists believe that this level of CO_2 uptake by the ocean will continue for many more years. As a result, of which acidification of the world ocean occurs, i.e. decrease in pH (since 1890, ocean acidity has increased, and pH has fallen from 8.2 to 8.1, and in some areas even to 8.0) [35]. (For example, although it is still weakly alkaline water, it is no longer alkaline enough for corals, mollusks, and other marine organisms, and they "die en masse".)

Fig. 18. Part of the "garbage island" of plastic in the Pacific Ocean

(photo The Ocean Cleanup)

By absorbing excess heat and carbon dioxide, the oceans slow down climate change, but this negatively affects aquatic ecosystems. After all, the world ocean is also a source of food and livelihood for several billion people on the planet.

Unfortunately, the oceans are increasingly turning into the world's garbage dump. For example, a huge floating "island" of plastic debris was found on the surface of the Pacific Ocean between California and the Hawaiian Islands [36] (Figs. 18). The mass of plastic is estimated at three million tons (80% - plastic bottles and containers), and the area is approximately 1 million square km. However, research conducted by Australian scientists has shown that there are additionally approximately 15 million tons of plastic waste less than 5 mm in diameter at the bottom of the world's oceans, which is 5 times the mass of plastic that "floats" on the surface of the ocean - 3 million tons. Plastic debris in the Pacific is responsible for the deaths of millions of seabirds and marine animals. Thus, Spanish

environmentalists in 2018 found more than 29 kilograms of plastic in the stomach of a dead 10-metre sperm whale [37].

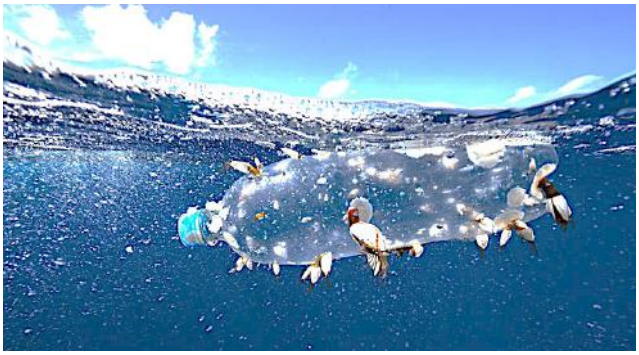

Fig. 19. Plastic bottle from the "garbage island" (photo Justin Hoffman, Greenpeace)

As shown in Fig. 19, a plastic bottle from the "garbage island" is literally covered with mollusks, crabs, and barnacles that bite off microparticles of plastic from the bottle. These clams and crabs will then be eaten by larger fish, and these microplastics will move up the food chain, ending at the human dinner table.

How can the world ocean be protected from plastic waste?

A) Avoid plastic bags. The US and Europe, then Canada and Australia are phasing out plastic bags. Kenya and Tanzania have recently joined. The new rules will force shoppers to reorganize: if they previously received plastic bags for free in stores, now they will be forced to carry their own shopping bags with them or buy cloth bags at the store checkout for little money.

B) For plastic bottles and plastic containers - the transition to biodegradable plastic. Such plastic has already been created in laboratories (https://www.sciencenews.org/).
Bioplastics are plastic materials produced from renewable biomass sources. Therefore, scientists from the University of California, Berkeley, developed such plastic for packaging. With moderate heat, enzyme-laced films of this plastic disintegrate within some weeks. British startup Polymateria has also developed a completely biodegradable plastic.

VIII. CONCLUSIONS AND RECOMMENDATIONS

The recipe for solving all the previous problems of mankind was the transition to a higher technological stage: from a raw food diet to making a fire, from picking berries and nuts to settled agriculture, from the Stone Age to the Iron Age, and from a horse to a "Ford". Climate change problems must be approached in the same way.

An analysis of the changes in the conditions of human life on Earth allows us to draw the following conclusions:

1. Climate change on the Earth has led to a sharp increase in hurricanes, floods, wildfires, droughts and other natural disasters, and it has led to a huge increase in financial damage to federal and local budgets.
2. In replacing fossil fuels with green energy (sunlight plus wind), humanity is moving on the right track and moving quickly and confidently. In replacing traditional gasoline and diesel vehicles with electric vehicles, humanity is also moving on the right track but is not moving fast enough.
3. It is necessary to strengthen building codes. It is necessary to allow the construction of only "hurricane-resistant" residential and public buildings in any hurricane-prone area. This is especially true for 1-2-story residential houses. It should be monolithic concrete or foam concrete, and even better - reinforced concrete; load-bearing columns must be firmly fixed in the ground.
4. As in the case of hurricane-prone areas, similar recommendations apply for fire-prone areas: it is necessary to allow the construction of only "fire-resistant" residential and public buildings in any fire-prone area. This is especially true for 1-2-story residential houses. It should be monolithic concrete (Fig. 4). However, in this case, it will be the so-called refractory or heat-resistant concrete or fireclay.
5. In areas prone to flooding, it is necessary to design and build powerful dams and/or breakwaters, and also powerful drainage systems such as the Tokyo drainage system.
6. Electrical power cables in all hurricane hazardous (as well as fire hazardous) areas should be laid exclusively underground through cryogenic superconducting underground cables (Fig. 8), in watertight and heat-resistant shells.
7. Hazardous fire regions should be sufficiently completed by aircraft and helicopters with a large load capacity for firefighting. All areas of the fire must be completely covered by a fire extinguishing agent (powder, foam, water).
8. To prevent wildfires, we urgently need to start utilizing everything in the forests that kindle: dried twigs, dead trees, grasses, and shrubs. It will be faster to restore burnt forests with the help of "seed bombs".
9. It is necessary to return to nuclear power but to small modular nuclear reactors (SMNRs) with a capacity of up to 300 MW. With their help, low-

enriched uranium and even nuclear waste from traditional reactors can be used as fuel.

10. We need to use heat pumps much more to generate heat pumping out "excess heat" from the environment.
11. The world has become a popular so-called “zero-energy house”, i.e. a building that is highly energy efficient, able to independently generate and save energy and consume it from its own sources throughout the year.
12. It is necessary to abandon cattle breeding (while maintaining more environmentally friendly poultry farming) and switch to artificial meat and milk.
13. Cultivation of agricultural crops should be transferred into so-called vertical farms. A vertical farm is approximately 10 times more efficient than a greenhouse and 100 times more efficient than in an open field.
14. Minimize food wastage at all stages - from harvesting and storing crops to discarding expired products.
15. It is necessary to completely abandon the current bio-non-degradable plastic in favour of biodegradable plastic.

After reading this section, any government official will say: "It's too much expensive!" Well, but 20-30-40 billion dollars damage every year - is it NOT expensive?...

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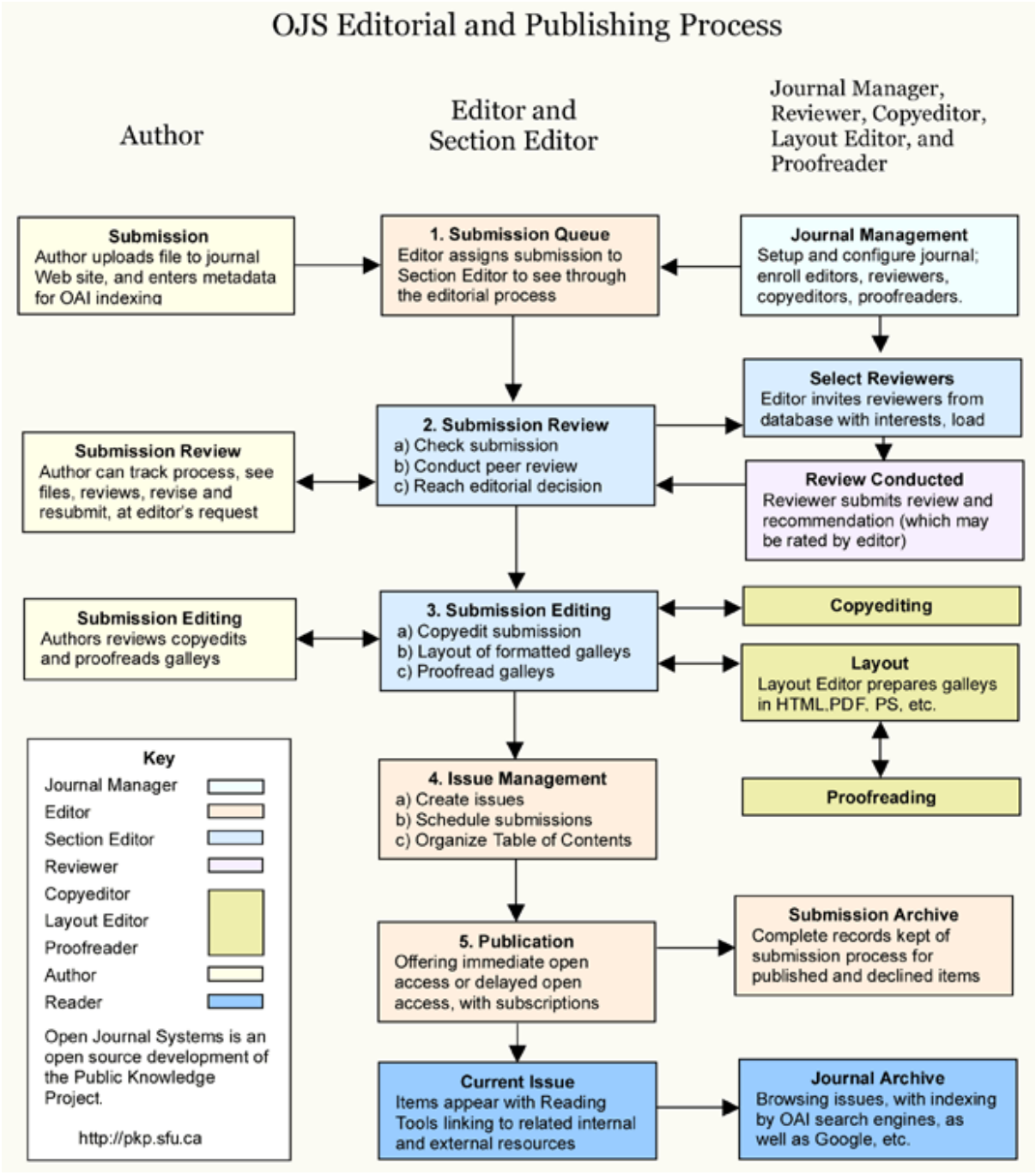

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