BIOAUGMENTATION: THE WAY OUT OF MALNUTRITION IN AFRICA

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ABSTRACT

Malnutrition is a plague created as the world advances more into era of innovations and discoveries, the more the human activities the more the damages caused on soil and the environment in general leading to food scarcity and many problems around the world especially in developing countries. The adverse effect of human activities like mining, oil spillage, wars and indiscriminate disposal of waste have rendered the soil useless for agricultural practices. The declining state of soil nutrients is mainly one of the causes of malnutrition and the need for improving the soil nutrient is inevitable to the eradication of malnutrition especially in developing countries of Africa. The need to augment soil nutrients is a necessary anodyne to mitigate the scorching fingers of poverty and malnutrition. Many approaches have been employed over the years to alleviate malnutrition but all to no avail. Bio-augmentation is a way out of poverty and malnutrition in Africa. An ecofriendly and cost effective bioaugmentation is composting, which does not require technical know-how and could be done domestically making use of plant and animal waste without looking for consortium to inoculate. Conclusively, if Africa could make it a point of duty to rejuvenate deteriorated soil nutrients by employing bio-augmentation through the usage of plant and animal waste, agricultural practices would experience a boom and malnutrition would be reduced drastically.

INTRODUCTION

Africa is the second largest continent in the world known for its natural resources, game reserves, pleasant verdure and great weather/climatic condition but unfortunately, Africa is also known to constitute developing countries struggling with a lot of fundamental problems associated with underdevelopment like political war, civil war, famine, lack of basic amenities to mention a few. One of the major problems common to most African countries is low food availability/malnutrition, and this is as a result of some factors like war (Uchendu, 2018), oil spillage (Ordinioha and Sawyer, 2008), price inflation (World Bank, 2006; Bain *et al.*, 2013), overpopulation (Monika and Mercedes, 2005), agent of weather/climate change (Arnell, 2004; WHO, 2012; Ringler *et al.,* 2013), political instability (Smith and Haddad, 2000), financial constraint due to poor governance and mismanagement of funds/resources (FAO, 2011; Bain *et al.,* 2013); all these sum up to increment in poverty at high pace.

Poverty is simply, the inability to provide for or satisfy basic human needs and this include food (Childers and Urquhart, 1994; FAO, 2011). All these causes of poverty/malnutrition vary across different geographical areas/socio-economic zones in Africa. Food is inevitable to

human's survival and if not consumed nutritionally and regularly, it is of no use to the consumers. Nutrition, which encompasses the essence of feeding, is the science that deals with the interaction of food constituent like nutrients, food additives, bio-available secondary metabolites in order to give maintenance, development, health and fortification to an organism/man. Anything outside the confines of nutrition as regards feeding is malnutrition and according to Bain *et al.* (2013), malnutrition simply conveys the meaning of bad, over and under nutrition.

Malnutrition is as severe as hindering the normal bodily performance, growth, pregnancy, lactation, and recuperation from diseases (Bain *et al.*, 2013). It was estimated that close to 30% of people including infants and elderly are suffering from multiple form of health complications as a result of malnutrition and also 49% out of the 10million death yearly among children in the age bracket of five years old are also associated with malnutrition and its complications in developing countries in which most of them are in Africa (WHO, 1999; Bain *et al.*, 2013). In Africa within the year 1965-1969, the poverty rate rose at an average of 55.8% and had been rising; in 1995-1998 the poverty rate was at the average of 64.9% (UNCTAD, 2002).

The World Bank in 1998 estimated that in Africa, around 46% of the total population were living below the poverty line (World Bank, 2001), these shows that poverty rate in Africa had been increasing at a very high pace over the years. Some African countries are regarded as the poorest in the world due to their per capita income (in US dollars) of their inhabitants. Countries like Togo, a West African country with over 7 million people majorly have a per capita income of $670 per year (Tunji *et al.*, 2005; WHO, 2013).

Sierra Leone is also regarded as one of the poorest country in the World due to the brutal civil war in the interim of 1991 – 2002 and as a result has a per capita income of $516 per year. Niger is an African country with over 17 million residents and over 80% of its land are covered by the Sahara desert and the remaining part of the land are troubled by incessant droughts and desiccation and as a result of this have a per capita income of $477 per year. Mozambique has a population over 24 million residents with a per capita income of $476 per year. Madagascar has over 69% of its population living below poverty of $1 per day, and the rest of the population has a per capita income of $459 per year. Democratic Republic of the Congo has over 80 million population with a per capita income of $449. Central African Republic is of the poorest countries in the World with a population of above 4.7 million and a per capita income of $430 per year (World Bank, 2001). Malawi has a population of 16 million people highly weighed down with high rate of HIV/AIDS, corruption, poor hygiene and malnutrition; very few segment of the population have a per capital income of $351 per year. Burundi is one of the poorest countries in the world with a population of over 11 million residents with average income of around $307 US dollars per year, South Sudan is the poorest country in Africa with a per capita income of $303 per year (World Bank, 2001; Bain *et al.*, 2013; WHO, 2013).

In Nigeria, the level of poverty is also alarming (Omoyibo, 2013), even with the professed and exaggerated economic development, poverty is still on the increase mostly in North-West and North-East geopolitical zones of Nigeria (Dauda, 2017; Danaan, 2018). Over the years in Nigeria, several poverty alleviation programs have been adopted such as: Agricultural Development Programme, launched in 1972 (Adegboye, 1991); Operation Feed the Nation, instituted in 1976 (Forrest, 1981; Anikpo, 1985); Agricultural Credit Guarantee Scheme established by decree in 1977 (Garba, 1987; ACGSF, 2007); Green Revolution introduced in 1980 (Adeyemo, 1984) but all to no avail on the evidence of present situation in Nigeria, all the scheme adopted over the years are failing or already failed.

Major Causes of Poverty/Malnutrition in Africa

The extreme prevalence of malnutrition in Africa is relatively high especially in sub-Saharan Africa compared to other continents of the world due to some causes which include the following:

I. Political Instability and Lack of Commitment

Despite all the Natural resources found in so many African Countries, some of the inhabitants still languish in poverty and this is partly due to the political instability and lack of commitment of the leaders to the common touch. Political instability had led to lots of backwardness in Africa; leaders had lost their patriotic sense to embezzlements. War, conflicts, riots to mention a few are rampant in African countries due to controversies over natural resources, lands, food, water, political issues and power (Uchendu, 2018). Agricultural practice cannot thrive where there is war or lack of funding from the government. Poverty/malnutrition is the inevitable offspring of war and these have really robed Africa of its resources and potentials.

Furthermore, War has brought about displacement of citizens for examples Sierra Leone, Sudan, Botwsana, South Africa and in Nigeria; 'Boko Haram' and 'herds men', have troubled the waters of peace in the country and as a result aggravating poverty and malnutrition rate in concerned States within the country. Corrupt leaders, Dictators and oppressors over the years have frustrated the livelihood of many Africans making survival harder (Uchendu and Abolarin, 2015).

II. Oil Spillage

Oil spillage has always being detrimental to the eco system. Some African countries are among the highest crude oil producing countries all over the world; Nigeria produces 1,900,000 barrels per day, Angola – 1,507,000 barrels per day, Algeria-1,171,000 barrels per day, Egypt-582, 000 barrels per day, Libya-528,000 barrels per day, Equatorial Guinea- 317,000 barrels per day to mention a few but while all these countries flourish in oil, there have been environmental degradation resulting in depletion in soil nutrients, crop death, acidic rain and above all farming/malnutrition (Ihejiamiazu, 1999; Inoni *et al.*, 2006). Since the discovery of oil in 1956 in Nigeria the highest oil producing country in Africa, a lot of havoc has been wrought on farming lands in the areas, to be specific Beyelsa State (Ordinloha and Sawyer, 2008).

III. **Agent of Weather/Climatic Conditions**

Weather conditions of some African countries rendered the agricultural practice of such countries almost impossible due to extreme sunlight or heavy rainfall. African countries like Kenya, Somalia and Niger are surrounded by deserts; Niger has 80% of its land area covered by the vast expanse of Sahara desert leading to incessant droughts and desiccation in the country. Also, incessant rainfall could lead to soil leaching resulting in low crop yield, price inflation of farm produce and financial constraint (Ringler *et al.*, 2010)

IV. **Indiscriminate Disposal of Industrial Effluents**

The pace of industrial developments and activities this dispensation have experienced are greater than the industrial growth of the past dispensation. Over the years, industrial activities have highly accelerated and as a result higher waste have always been generated daily and are discharged on land or into water body (Chhonkar *et al.*, 2000; Fakayode, 2005; Kanu and Achi, 2011). Although waste water could serve as sources of nutrient and organic matter to soil and as result help in crop production (Van der Hoek *et al.*, 2002; Roy *et al.*, 2010). But in urban metropolis where brewery industrial effluent (Kanu *et al.*, 2006), Tannery industrial effluent (Onwuka *et al.*, 2005; Kanu and Achi, 2011), chemical industrial effluent (Odokuma, 2003), Hospitals effluents (Kristell *et al.*, 2012; Eze *et al.*, 2016) to mention a few are discharged on daily bases; the waste water would contain hazardous constituents including higher trace elements, heavy metals (Siebe and Cifuentes, 1995) and precursors of infections and mutation

and as a result crops are stunted or destroyed, man is weakened and inevitably incurring poverty and severe malnutrition.

V. Agricultural Chemicals Residue in Soil and Food

One of the challenges agriculture is facing in Nigeria is relatively low soil fertility and weed/pest control and management. Due to low level of organic matters, nitrogen, phosphorus and potassium in the soil (Osundare, 2008; Loks *et al.*, 2014), the use of fertilizer is adopted. Fertilizers are chemicals containing plants nutrients compounds manufactured for the purposes of improving/supplementing soil nutrients (Asiegbu, 2006). Indiscriminate and over use of fertilizers could result in contamination of water bodies both surface water and ground water and finally affecting the crop yield leading to malnutrition. Also the use of pesticides has engineered malnutrition. Pesticides are toxic chemicals meant to control pests and weeds. Pesticides include herbicide, insecticides, bactericide, fungicide, insect repellent etc (Randall, 2014). Worldwide, the consumption of herbicides residue in food is 47.5%; insecticides residues are 29.5% and fungicides residues are 17.5% while others account for 5.5% only (Shobha, 2012). Pesticides could cause poisoning if consumed (Attar *et al.*, 2009; Saravu *et al.*, 2013).

Inevitably, soil is the backbone and foundation of all human activities, especially agriculture. Eswaran *et al.* (1997) reported that due to industrial activities and desert regions, 55% of the land in Africa is unsuitable for cropping, and that was over two decades ago, in the interim, lot of industrial/ human activities must have rendered the lands even more useless for farming, so, affirmatively, enriching and maintaining soil nutrients for farming is of utmost importance in Africa if poverty and malnutrition would be mitigated massively.

Soil constitutes five major constituents (1) mineral matter from disintegration of rocks over time (45%); (2) organic matter from decaying organisms (5%); (3) air (20-30%), which includes, Oxygen, Carbon (IV) Oxide; and (4) water (20-30%). The solid part of the soil constitutes the mineral and organic matters, while water and air occupy the pore spaces between the soil particles. (5) The fifth constituents are the most important components and these are the living organisms (plants, microorganisms (bacteria and fungi), nematodes, and arthropods) that inhabit the soil and contribute to the soil enrichments. The microorganisms present in the soil play many roles which include: nitrogen fixation, bioremediation, biocatalization and bioaugmentation. Industrial/human activities like war, industrial effluents, oil spillage, emission of poisonous gases and indiscriminate use of agricultural chemicals have been highly detrimental to the soil microorganisms and as a result rendering the soil destitute of enrichments. The rejuvenation and enrichment of contaminated soil has to start with the thriving of beneficial microorganisms in the soil. Bioaugmentation is one of the reliable approach to soil rejuvenation and enrichment in Africa.

Bioaugmentation

Bioaugmentation has grown with time as early as 1800s, (Gentry *et al.*, 2004; Singer *et al.*, 2005) soil had been improved and enriched through plantation of crops capable of depositing more beneficial bacteria into the soil for example legumes which are known for their symbiotic *Rhizobium spp* capable of fixing nitrogen from the atmosphere, further more bioauguentation could be employed in food enrichment and crop preservation (Lebeau, 2014). Many more researchers have defined bioaugmentation from some angles; Lebeau (2014) simply defined bioaugmentation as proffering a solution to the problem of soil contamination through biological methods. According to El Fantroussi and Agathos (2005), biogumentation is the practice of removing contaminants from the soil or other biotope by introducing strains or consortia of microorganisms. Also, Dejongbe *et al.* (2001) reported that bioaugmentation is the

approach of increasing the metabolic activities and capabilities of the soil microbiota. Bioaugmentation is the professional practice of introducing microorganisms or microbial cultures into a given environment to perform bioremediation and enrichments (Alvarez and Illman, 2006; Da-Silva and Alvarez, 2010). Bioaugmentation constitutes two approaches (Vogel and Waler, 2002; Da-Silva and Alvarez, 2010). The first approach is based on the introduction of microbial cultures or microorganisms with desired catabolic properties to complement or replace the already surviving microorganisms' population. In this approach, the selected consortia are capable of out competing the native microorganisms present in the contaminated environment in order to occupy a specific metabolic niche within the contaminated environment (Vogel and Waler, 2002).

The second approach is the addition of a higher concentration of microorganisms or consortia that only act as biocatalysts monetarily to degrade large amount of targeted contaminants before becoming inactive; the inactivity could be as a result of abiotic and biotic stress encountered in the new environments (Duba *et al.*, 1996; Da-Silva and Alvarez, 2010). The level of toxicity, pollutant concentration, pH, water availability/activity and, very low nutrient and competition with the native microorganisms could result in the declining/inactivity of the consortia in the new environment after a while (Gentry *et al.*, 2004); in cases like this re-injection of the consortia is advised overtime.

In Africa, and throughout the world, soil is the major backbone of agricultural practices but it is a pity that the soil are heavily polluted in both developed and developing countries and to make it worse, laws and government approaches are not helping (Lebeau, 2014), so, the need for bioaugmentation is indispensable to the survival of agriculture and food availability throughout the world most especially Africa.

Bioaugmentation Factors

The success of soil bioaugmentation in other to improve crops yield and food availability depends on two factors (Bopathy, 2000; Hazen and Stahl, 2006; Lebeau, 2014); they are Abiotic and Biotic factors.

Abiotic Factors

Temperature

Diels and Lookman (2007) reported that bioaugmentation is affected badly more in extreme temperate and very cold regions due to the fact that bioaugmentation is mostly enhanced within the temperature range of 5-30^{0}C. Microorganism mostly used as inoculum in bioaugmentation are mostly mesophiles which grow best in moderate temperatures, most Africa countries are neither too temperate nor too cold, bioaugmentation process would thrive in Africa considering this factor.

pH

The potential hydrogen (pH) of the soil also determines the success of bioaugmentation efficiency, Grundmann *et al*. (2007) and Lebeau (2014) reported that the most efficient pH range for bioaugmentation is within 5-8, which are mostly normal ranges in soil. Goux *et al.* (2003) opined that the bioaugmentation of atrazine polluted soil by using two different microbe consortia, atrazine degradation was effective at pH>7 but only one consortium out of the two could degrade atrazine at pH 6.1, these lent credence to the crucial consideration of the soil pH at bioaugmentation. Chen *et al.* (2007) also reported that the pH for phenol and Trichloroethylene degradation were observed to vary depending on whether the microbial cells were free or immobilized; the degradation was notice at pH>8 for immobilize cells while at

pH6.7 and 10, the degradation was not observe with the free cells, it was reported that this could be as the result of the mass transfer limitation that inhibits physic-chemical alterations in the ,matrix immobilizing cells in spite of steady modification in the surrounding environment.

Aerobic Conditions

The soil bioaugmentation also depends on aerobic conditions, Lebeau (2014) reported that the use of Oxygen gas as a final oxidant (electron accptor) has been observed to produce one of the most suitable reactions and also stimulate great deal of biodegradation reactions in bioaugmentation. According to Diels and Lookman (2007) under the aerobic conditions, a yield of 0.05-0.6 mol biomass mol carbon^{-1} could be obtained while under anaerobic conditions the yield falls to 0.04-0.083 mol carbon^{-1}. Although, Lebeau (2014) suggested that different bioaugmentation mechanisms require different final electron acceptors depending on contaminant features. Furthermore, in soil contaminated with petroleum hydrocarbons the most preferred and thermodynamically appropriate electron acceptors for the consortia activities is oxygen gas due to the highly reduced state of petroleum hydrocarbons (Lebeau, 2014). Although, the degradation of chlorinated solvents in the soil are different from that of petroleum hydrocarbon and some other oxidized compounds based on the level of halogenation and as a result the relevant condition for biodegradation in bioaugmentation will be anaerobic.

Nutrients Availability

Consortia inoculated for bioagumentation into the soil require nutrients (organic matter, minerals) which should be readily accessible in the soil at a steady rate for long period of time. Organic matter is very crucial in the efficacy of bioaugmentation. Organic matter are readily available substrate consortia utilize in bioaugmentation because they are good microniche material and also good sorbent for pollutants (Mrozik and Piotrowska-seget, 2010).

Soil Humidity and Hydraulic Factors

In bioaugmentation, the soil humidity covertly determines the soil aeration level, the physical and hydraulic properties of the soil should be put into consideration if efficient bioaugmentation would be achieved (Kinsall *et al.*, 2000). The soil texture determines the hydraulic properties of the soil and microbial transport within the soil. Microbial movement is dependent on the porosity, water movement and hydraulic properties of the soil and this should be crucially considered in bioaugmentation process.

Biotic Factors

Bioaugmentation centers the usage of microorganisms in the enrichment of the soil or any biotope, and this involve the inoculation of microorganisms which could be affected by competition with the normal microflora of the soil/biotope (Genty *et al*., 2004), earthworm bioturbation (Monard *et al.*, 2008), pollutant level and also protozoan grazing (Genty *et al*., 2004; Lebeau, 2014). Moran *et al.* (2006) reported the declining in inoculated microbial population as a result of competition and pollutant level. Colores and Schmidt *et al.* (1999) also reported the impairment of microbial colonization *of Sphingomonas chlorophenlica* strain RA2 in a soil contaminated by pentachlorophenol. Earthworm bioturbation through the biogenic reworking and transport of soil particles, the inoculated microorganisms are affected (Monard *et al.*, 2008)

Microbial Inoculum Choices for Soil Bioaugmentation

Microbial inoculum should be chosen in relevance to performance or affinity of microorganisms towards pollutants which include tolerance to high concentration, osmotic

pressure, change in chemical forms etc. and also the consortia should be characterized and stored in a culture medium where their catabolic ability will be preserved (Thompson *et al.*, 2005; Lebeau, 2014). It should be noted that bacteria consortia thrive more with depth as the population of actinomycetes and fungi declines (Boopathy, 2000), the depth of the area to be bioaugumented should be taken into consideration in selecting consortia.

According to Mrozik and Piotrowska-seget (2010), Gram negative bacteria are always considered over Gram positive bacteria; Gram negative bacteria such as *Pseudomonas spp, Flavobacterium spp, Achromobacter spp, Sphingobium spp* and *Alcaligenes spp* are often used Although Gram negative bacteria carry the tag "superbug" which are often pathogenic the most but also considering their resilience, bioremediation enzymes secretion and catabolic superiority, they should take precedence in the selection of microorganisms for bioaugmentation (Singer *et al.*, 2005) but Lebeau (2014) suggested the consideration of Gram positive bacteria such as *Bacillus spp, Mycobacterium spp* and *Rhodococcus spp.* too. Fungi such as *Aspergillus spp, Mucor spp, Penicillium spp* and *Verticillium spp* should be considered, although most of these moulds are toxigenic but further control measure could be employed after the bioaugmentation process is completed.

As a result of industrial activities like indiscriminate discharge of industrial effluent, landfill, oil spillage and mining, African soil had deteriorated over the years, posing great threat to agriculture and livelihood of all inhabitants. Soil rejuvenation in Africa is of paramount importance if Africa will be rid of famine and malnutrition. Oil spillage and uncontrolled landfills pose more threats than the rest of the factors causing soil-nutrient deterioration, Babajide and Rees (2014) reported that oil spillage in underdeveloped countries often pose larger threat to the environment due to lack of prompt response to the problem and lack of technology to combat the challenge, than the developed countries (Plohl *et al.*, 2002; Babajide and Rees, 2014).

Oil spillage disrupt and affect the livelihood of inhabitants in many areas, for example in Bodo and Ogoni community, Niger Delta regions of Nigeria, Shell petroleum company indiscriminately spilled several million barrels of oil on their land in 2009 leading to the pollution of their farmlands, rivers, water bed, and as a result putting an end to fishing, farming and other vocations related to agriculture in the area till date (Tregaski, 2013). If prompt action of clean-up or bioremediation is not taken at the exact period of oil spillage, post-spill ecological impacts are more detrimental to human and the environment leading to death or bioaccumulation over time (Babajide and Rees, 2014).

Cost Effective Bioaugmentation Strategy to Improve African Soil

Over the years several bioaugmentation processes have been explored which have been yielding gradual results year in year out but most are expensive and require technical now how. On the other hand strategies like composting has been reported to be more efficient, ecofriendly and easy to carry out.

Composting Bioaugmentation

Composting is a simple cost friendly way of utilizing organic matters like manure, animal dung, plant waste, sewage etc. to aerobically degrade pollutant (Gestel *et al*., 2003; Babajide and Rees, 2014). The process involves the mixing of organic matter waste with pollutant like hydro carbons in order to produce microbial consortia that would engineer the biodegradation of the pollutant. The process would generate increased temperature of about 50^0C and a neutral pH resulting in massive generation of nutrient for the consortia (Zouboulis and Moussas, 2011).

In the case of oil spill, the compost process generates higher temperature in which the compost engineers the hydrocarbons degradation (Pignatello and ing, 1996; Zouboulis and Moussas, 2011). If the organic matter wastes are not fresh, the thermophiic phase will not occur and thus reduce the efficiency of the process (Gestel *et al.*, 2003).

Furthermore, Namkoong *et al.* (2002) reported that sewage sludge composting degrade more hydro carbon than that of plant waste and this could be as a result of microbial richness of sewage sludge. Composting utilizes consortia derived from the organic matter which make the process easier, cost effective, ecofriendly, and also providing an end product of compost manure that would enhance agricultural farming after the bioaugmentation is completed. The only disadvantage of composting is that it takes longer period of time to complete (Zouboulis and Moussas, 2011).

CONCLUSION

Since 1870's when the world population literarily first experienced high food prices leading to great malnutrition, many other challenging factors have been contributing more to the malnutrition problems over the years till today, the effect of different causes resulting in malnutrition has increased more than five times attaining 6.7 billion malnutrited people around the world today. It is estimated to reach 9 billion people in 2050 (Younis *et al.*, 2015). In other to overcome the ever increasing malnutrition problems, and to provide food to seemingly increasing 2 billion people, food production has to be doubled by 2050, how would Africa, a developing country, be emancipated in all areas necessary to put food on the already malnutrited people?. It would be out of place to require of people destitute of food to eat, some mainly because of high price of food commodities as a result of nutrient depleted soil leading to low farm yields and inflation, to engage in an approach that would incur expenses on their already poor life.

Africa needs more eco-friendly and cost effective strategy to battle this challenge of malnutrition. Bioaugmentation is a reliable way of rejuvenating soil nutrient but it would be more effective and easy if it the processes are easier and cost effective to carry out. Composting out of many other strategies stand out, it is easy, no technical know-how needed and also eco-friendly giving back the nutrients taken from the soil through pollution and also bioremediating the pollutant. Africa will be rid of malnutrition if bioaugmentation could be taken into consideration at national level.

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