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EFFECTS OF ALOE VERA GEL PRE-TREATMENT AND DRYING METHODS ON SOME QUALITY PARAMETERS OF SLICED OKRA

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ABSTRACT

Okra (Abelmoschus esculentus L.) is a tropical and sub-tropical vegetable crop, usually desired both during its peak season in its fresh form and during the off-peak season in its dried form. Discoloration during thermal drying of okra often results in its reduced acceptability in dried form. This study investigated some quality parameters of differently dried okra slices. The okra slices were subjected to freeze-drying at -420 ºC, sun drying at 41 ºC and cabinet drying at 60 ºC, while slices pretreated with aloe vera gel were also subjected to sun drying and cabinet drying at 60 ºC. Fresh and dried samples were analyzed for moisture content, reconstitution index and colour retention. Results of the analysis was subjected to statistical analysis using Analysis of Variance (ANOVA). Results showed that the freeze-dried samples had the lowest moisture content (6.33) while the aloe vera treated samples generally had significantly higher moisture content among all the dried samples. The result further showed that the reconstitution index of the samples ranged from 0.72 for cabinet dried aloe vera treated samples to 0.63 for untreated sundried samples but was not significantly different from each other. The greenness of the fresh okra pods ranged from -12.70 to -13.76 while -4.62, -6.58, -8.51, -5.70 and -8.20 were reported for freeze-dried, untreated sundried, untreated cabinet dried, aloe vera treated sundried and aloe vera treated cabinet dried samples respectively. The untreated cabinet dried samples had the highest lightness (a) value (-8.51) among all the dried samples but was significantly indifferent ($p \leq 0.05$) from cabinet dried aloe vera treated samples which had a value of -8.20. Results further showed that all the dried samples except the sundried aloe vera treated samples scored above average in terms of colour retention. It was concluded that for the food industry, sundried and cabinet dried untreated okra slices as well as cabinet dried aloe vera treated okra slices may be equally acceptable in terms of colour. It is recommended that steam blanching as a pretreatment to cabinet and sun drying should be studied.*

KEYWORDS: Okra, Aloe vera, Drying, Colour

1. INTRODUCTION

Consumers around the world demand for food of high-quality and extended shelf life with its desirable inherent qualities such as colour, flavour, aroma and reconstitution stability. This has led to many processing techniques which have been developed to extend the shelf life of unstable foods while retaining its desirable inherent qualities. Chlorophyll containing vegetables are one of such shelf-unstable food materials, capable of losing its chlorophyll during thermal drying. Chlorophylls are highly susceptible to degradation during processing resulting in colour shift of chlorophylls from brilliant green to olive brown compounds such as pheophytin and pheophorbide in senescent tissues (Koca *et al*. 2006). Chlorophyll degradation is significantly mediated by factors such as enzyme chlorophyllase, heat, light, oxygen, chemicals and acids (Gunawan and Barringer, 2000; Koca *et al*., 2006).

Okra is a vegetable crop belonging to the genus *Abelmoschus*, family *Malvaceae* and has two main species: *Abelmoschus esculentus (L.) Moench* and *Abelmoschus caillei (A. Chev.) Stevels.* It is an important vegetable crop native to tropical and sub-tropical regions of the world, especially

Africa. It is a popular non-seasonal crop (although its peak period is usually in the raining season) usually enjoyed for its tender, delicious and slurry pod with brilliant green colour. Okra is usually desired, both during its peak season in its fresh form and off-peak season in its dry form. Thermally dried okra however absorbs a measure of ethylene, thus losing its attractive colour resulting in loss of preference, acceptability, and pleasantness. Discolouration during thermal drying of okra is mainly related to the replacement of magnesium ion in the porphyrin ring by hydrogen ions and subsequent formation of pheophytin and pheophorbide that result in a change in colour from bright green to dull olive green (Heaton and Marangoni, 1996; Toivonen and Brummell, 2008).

To stabilize and retain chlorophyll in stored green vegetables such as okra, various processing treatments have been applied. Olivas and Barbosa-Canovas (2005) studied the retention of chlorophyll in green apples using edible waxes, Gorny *et al*. (2002) studied the quality changes in fresh-cut pears slices by controlled atmospheres packaging, Aguayo *et al*. (2006) studied the atmospheric modification on quality changes in fresh –cut strawberries while Nwosu *et al.* (2016) studied the storage stability of cucumber using aloe vera gel. Globally, freeze drying of food materials is accepted as the best and most effective way of preserving foods of unstable colour and properties, however, freeze drying technology is sophisticated, expensive for the poor rurals and cannot be domesticated in areas with unstable power supply such as Nigeria.

Aloe vera, a tropical and subtropical plant is well-known for its numerous medicinal properties. Its gel, alternative to synthetic preservatives such as sulfur dioxide, is colourless, odourless (Jawadul *et al.,* 2014) and nutritionally safe to consume. Aloe vera gel-based edible coatings have been shown to prevent loss of moisture and firmness, control respiratory rate and maturation development, delay oxidative browning and reduce microorganism proliferation in fruits such as table grapes, sweet cherries and nectarines (Castillo *et al*., 2010;Ahmed *et al*., 2009; Martinez-Romero *et al*., 2006). This gel operates through a combination of mechanics, forming a protective layer against the oxygen and moisture of the air and inhibiting the action of micro-organisms that cause food borne illnesses through its various antibacterial and antifungal compounds (Serrano *et al*., 2006).

Several investigations have been reported on the optimum drying parameters, pre-treatments and the drying kinetics of okra (Pendre *et al.,* 2012; Shivhare *et al*., 2000; Ouedraogo *et al.*, 2017; Doymaz, 2005; Olaniyan and Omoleyomi, 2013; Shivhare *et al*., 2000); But, little can be found in literature on the quality retention in terms of colour of dried okra. This study investigated the effects of aloe vera gel pre-treatment and drying methods on some quality parameters of sliced okra with a view of retaining its chlorophyll.

2. MATERIALS AND METHODS

2.1 Materials

Freshly harvested and uninjured dwarf variety of okra (*Abelmoschus esculentus (L.) Moench)* was obtained from a rural farm, while fresh and healthy Aloe vera leaves were obtained from a horticultural garden, all in Ilorin, Kwara state, Nigeria. A hue and chroma colour analyser (Model number: CRL/FD/21/004) was used to analyse the colour of the okra samples. An electrically powered dryer designed and available at the Engineering and Scientific Services (ESS) Department of the National Centre for Agricultural Mechanization (NCAM) was used for the drying. The dryer which consists of a heat source, an air blower, the drying chamber and a chimney was instrumented with a temperature controller/ monitor, an airflow controller/ monitor and a thermocouple. The moisture content of fresh and dried samples were determined using a digital moisture analyser (Ohaus, Model number: MB90. Serial number: B707695969). A laboratory manifold freeze dryer (Labconco freeZone 1 litre capacity), model number: 700201000 available at the Central Research Laboratory of the University of Ilorin, Ilorin was used in this study.

2.2 Sample Preparation

The freshly harvested okra was washed to remove and spread on a screen to drain water. The tails and butts of the cleaned okra pods were removed by a stainless-steel knife while the slicing was done with the aid of NCAM developed okra slicer. The thickness of the sliced okra was measured to be an average of 1 cm. Aloe gel which lies underneath the green outer leaf rind of the plant was obtained by separating the outer cortex of leaves from the gel. The gel was blended with an electric blender for 3 mins at low speed to homogenize, and the resulting gel poured into a plastic bowl for use. Samples treated with Aloe vera and sundried were labelled as $\mathbf{A_{11}}$ while samples treated with Aloe vera and dried using a cabinet dryer were labelled as $\mathbf{A_{12}}$. Untreated samples dried using a dryer were labelled UT_2 while untreated sundried samples were labelled as UT_1. Freeze dried samples were labelled as FD_0.

2.3 Method

Three replicates of 2 kg each of A_{11} and A_{12} were immersed in the homogenised aloe vera gell for 7 mins. The choice of the immersion time was based on the preliminary investigation carried out on habanero pepper which showed that 7 mins was appropriate for immersion in aloe vera gel. The treated and the untreated samples was then dried using the various drying techniques. The cabinet drying of okra was carried out at 60ºC. The choice of 60ºC was based on preliminary investigation. The okra samples were pre-freezed in a laboratory blast freezer at a eutectic temperature of -49ºC for 28 hours. The pre-frozen slices were then quickly attached to the manifold flask for drying, while the collector temperature was set to -70ºC and the vacuum pump was at 0.0025mbar. The okra samples were allowed to dry for 17 hours.

The fresh and dried samples were analysed for colour using methods described by the hue and chroma colour analyser manufacturer manual. The colour analysis was determined using the CIE L * a * b * parameters. According to the CIE colour space, L * parameter represents brightness and changes between 0 (black) to 100 (white); the a * parameter gives the green (-a *) or the red (+ a *), while the b * parameter gives the yellow (+ b *) or blue (-b *) (Mc Guire, 1992; Manolopoulou and Varzakas, 2016). The colour analysis were performed before and after drying.

The samples were further analysed for moisture content using methods described by the moisture analyser manufacturers manual at a temperature of 105ºC for 30 mins using a 2g sliced sample. Reconstitution index of the dried samples were determined as a ratio of rehydration ratio to dehydration ratio as described by Kumar *et al*. (1991) and used by Shivhare *et al*. (2000). All analysis were carried out in triplicates.

All results obtained in this study were subjected to Analysis of Variance (ANOVA) statistics. A Statistical Package for Social Sciences (SPSS) software version 22, created by IBM group was used for this purpose.

3. RESULTS AND DISCUSSION

The result of the moisture content is presented in Table 1. From the Table, moisture content ranged from 84.77 % in the control sample to 6.33% in the freeze dried samples. The dried samples also showed significant differences in moisture content, indicating the different level of dryness of the sample. Among the samples, the aloe vera treated samples showed the highest moisture level of 9.41% and 9.99% for cabinet dried and sundried samples, respectively. This significantly high moisture level in the aloe vera treated samples indicates a possible lower drying rate compared with other samples at the same drying conditions. It appeared that the aloe vera gel may have filled up respiratory pores in the okra pod and provided a protective film on the surface layer of the pods which slowed down the rate of heat diffusion within the slices and trapped moisture between the outer green layer of the slices and the protective film provided by the gel. This may have lowered the drying rate and resulted to significant higher moisture content of the sample within the same drying time. This agrees with the findings of Nwosu *et al.* (2016), who reported a protective film created by aloe vera gel during shelf storage of cucumber. According to the authors, the protective film reduced respiration and moisture loss in fresh cucumber samples during shelf storage. Doymaz (2005) reported a higher final moisture content (15% wb) of okra (*Hibiscus esculentus L.*) variety dried at 60ºC. Table 1 further showed that the moisture content of cabinet dried aloe vera samples were not significantly different from the untreated sundried samples at $p \leq 0.05$, it however showed significant difference from its cabinet dried counterpart. This higher moisture content of aloe vera treated samples suggests a lesser shelf life under ambient conditions.

The result of the reconstitution index of the dried samples is presented in Table 1. The Table showed that the reconstitution index of the samples ranged from 0.72 for cabinet dried aloe vera treated samples to 0.63 for untreated sundried samples. All the samples showed a reconstitution index greater than 0.5. This implies that the ability to reconstitute when utilized in food systems is higher than average.

Table 1. Moisture content and reconstitution index of control and differently dried okra

Sample	Moisture content	Reconstitution Index
Control	84.77 ± 0.2^{a}	-
FD_0	6.33 ± 0.57^{e}	0.66 ± 0.29^{a}
UT_1	9.07 ± 0.80^{cd}	0.63 ± 0.01^{a}
UT_2	8.42 ± 0.58^{d}	0.64 ± 0.01^{a}
A_{11}	9.99 ± 0.08^{b}	0.71 ± 0.01^{a}
A_{12}	9.41 ± 0.28^{bc}	0.72 ± 0.01^{a}

Values are mean of three replicates ± SD. Valueswith different superscript along the column are significantly different ($p \leq 0.05$).

FD_0 - Freeze dried samples; UT_1 - Untreated sundried samples; UT_2 - Untreated samples dried using cabinet dryer; A_{11} - Samples treated with Aloe vera and sundried; A_{12} - Samples treated with Aloe vera and dried using a cabinet dryer

The results further showed no significant difference from each other at $p \leq 0.05$. It appears that the protective film created by the gel in the aloe vera treated samples did not reabsorb much moisture to trigger a significant difference ($p \leq 0.05$) during its reconstitution. Shivhare *et al*. (2000) reported similar values of 0.72 and 0.80 for water blanched and NaCl blanched okra (*Abelmoschus esculenrus*) variety respectively at a drying temperature of 55ºC.

The result of the colour analysis is presented in Table 2. The greenness of the fresh pods ranged from -12.70 to -13.76 while that of the dried samples ranged from -4.62 for freeze dried samples to -8.51 for untreated cabinet dried samples. The low a* value of the freeze-dried samples may have resulted from freezer-burn experienced by the samples at the eutectic temperature of -49ºC before sublimation could occur. Additionally, it is possible that at such low temperature, the magnesium (Mg) ion at the centre of the chlorophyll porphyrin ring degraded, leading to the collapse of the chlorophyll structure and formation of pheophytin; this may have aided in the pronounced brown colour of the freeze-dried samples. This implies for the food industry, that freeze drying of okra pods could lead to an unacceptable sensory colour. The untreated cabinet dried samples showed a significantly higher green colour (-8.51) at $p \leq 0.05$ than other samples under study. This may have resulted from the steady rate of heat diffusion under hot air drying as opposed to the possible sudden temperature and air velocity changes during sun drying. During cabinet drying of the untreated samples, the steady rate of heat diffusion and moisture diffusion may have increased the drying rate as reported by Doymaz (2005), giving little time for the collapse of chlorophyll and resulting in the brilliant green colour of the dried samples. During sun drying however, sun intensity and air velocity fluctuates per time, leading to differentials in the rate of heat and moisture diffusion. This is an indication that drying rate may be an important factor in the colour of dried okra slices as reported by Shivhare *et al*. (2000).

Table 2. Result of colour Analysis of the differently dried samples

Sample	Before Drying			After Drying		
	L*	a*	b*	L*	a*	b*
FD_0	47.02 ± 2.63^{a}	-12.80 ± 0.93^{ab}	28.58 ± 2.59^{a}	46.64 ± 2.18^{a}	-4.62 ± 1.33^{a}	14.38 ± 0.22^{a}
UT_1	44.40 ± 1.15^{b}	-12.70 ± 0.49^{a}	15.09 ± 0.71^{c}	35.56 ± 4.97^{c}	-6.58 ± 0.54^{b}	15.38 ± 2.43^{a}
UT_2	45.94 ± 0.60^{ab}	-13.21 ± 0.43^{ab}	29.49 ± 0.29^{a}	40.64 ± 0.08^{bc}	-8.51 ± 0.07^{c}	14.42 ± 1.24^{a}
A_{11}	46.42 ± 0.08^{ab}	-13.76 ± 0.03^{b}	19.04 ± 0.11^{b}	43.71 ± 2.11^{b}	-5.70 ± 0.10^{ab}	16.92 ± 3.33^{a}
A_{12}	41.18 ± 0.08^{c}	-13.18 ± 0.11^{ab}	17.64 ± 0.05^{b}	40.18 ± 2.89^{bc}	-8.20 ± 1.32^{c}	15.49 ± 0.81^{a}

Values are mean of three replicates ± SD. Values with different superscript along the column are significantly different ($p \leq 0.05$). L* = brightness, -a* = green, b* = yellow. FD_0 - Freeze dried samples; UT_1 - Untreated sundried samples; UT_2 - Untreated samples dried using cabinet dryer; A_{11} - Samples treated with Aloe vera and sundried; A_{12} - Samples treated with Aloe vera and dried using a cabinet dryer

Table 2 further showed that the sundried aloe vera samples which had a value of -5.70 showed no significant difference ($p \leq 0.05$) from the untreated sundried samples. It however appeared that the protective film created by the aloe vera gel, which also filled the respiratory pores of the okra pods, may have trapped enough moisture with adequate activation energy at the surface layer of the pods (with low air flow velocity), long enough to collapse some of the magnesium (Mg) ions at the centre of the chlorophyll structures. These collapsed Mg ions may have been replaced by hydrogen ions from the chlorophyll matrix, leading to the formation of pheophorbide with a characteristic dull olive-green colour as described by Heaton and Marangoni (1996), Toivonen and Brummell (2008). It is also possible that with the retention of moisture at the surface layer of the pods during sun drying of the aloe vera treated samples, adequate water activity (A_w) developed over time and catalysed slight enzymatic degradation at the soft surface tissues of the okra slices that promoted the dull olive-green colour of the dried samples. The cabinet dried aloe vera treated samples had a significantly higher value (-8.20) of a* than its sundried counterpart but showed no significant difference with the cabinet untreated samples which had a value of -8.51. This significantly higher value of a* than its sundried counterpart suggests that the air velocity was sufficient to break through the protective film created by the aloe vera gel and drive most of the diffused moisture away from the surface. This may also have helped in slowing down enzymatic action within the sample and promoted the diffused green colour of the dried sample.

Comparing the colour of the samples before and after drying, the freeze-dried samples differed the highest in terms of greenness, followed by sundried aloe vera treated samples which performed below average in terms of greenness. Other dried samples under study however performed above average. This implies for the food industry, that sundried and cabinet dried untreated okra slices as well as cabinet dried aloe vera treated okra slices may be equally acceptable in terms of colour.

4. CONCLUSION

Some quality parameters of differently dried okra have been revealed in this study. The study showed that there was no significant difference in the reconstitution index of both freeze-dried, aloe vera treated and untreated hot air-dried samples. The study further revealed that aloe vera treated samples had the highest moisture content among the dried samples irrespective of the drying method. The study also showed that the freeze-dried samples had the poorest colour in terms of greenness, followed by sundried aloe vera treated samples. Cabinetdrying had no significant colour difference in terms of greenness while all the dried samples except the sundried aloe vera treated samples scored above average in terms of colour retention. It therefore implies for the food industry, that sundried and cabinet dried untreated okra slices as well as cabinet dried aloe vera treated okra slices may be equally acceptable in terms of colour.

It is recommended that steam blanching as a pretreatment to cabinet and sun drying should be studied.

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DETERMINANTS OF ACCESS TO NCAM PROVEN TECHNOLOGIES ACROSS THE SIX GEO-POLITICAL ZONES

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ABSTRACT
The overall objective of this study was to assess the determinants to access National Centre for Agricultural Mechanization **(***NCAM) Proven Technologies across the six geo-political zones. The study was conducted through the use of a well-structured open and closed ended questionnaire administered through interview schedule to 200 respondents selected using a multistage sampling technique. The data collected were analyzed using both quantitative and qualitative statistics and linear multiple regression analysis. The findings from the study clearly show that the socio-economic characteristics of the 200 respondents are a major determinant in accessing agricultural technologies. More so, cooperative societies, household size, and educational status have positive relationship with access to information on agricultural technology; this has led to adoption of these proven technologies. The study also revealed that there is either limited impact of extension agents or lack of cooperation between NCAM and extension agents in the study area, only few (5%) of the respondents claimed that they source their information from extension agents.*

KEYWORDS: NCAM, Agricultural Technologies, Determinants, Processing Centers.

1. INTRODUCTION
The conventional view of agricultural development sees agriculture as the prime engine of growth and poverty reduction in poor countries. The view emphasizes small farm agriculture growing modern variety of cereal staples in relatively high potential and well-connected areas and supports the idea that agricultural development has to be based on increasing productivity of smallholder producers. In this context, limited access to the technologies that assist farmers in improving their production and later in selling their products thus causing low productivity, post-harvest losses and persistently low household income, is considered one of many reasons making farmers vulnerable to poverty.

For years, scientific and technological advancements have benefited farmers in the industrialized world by driving agricultural production. However, smallholder farmers who are responsible for 80 percent of the food in the developing world have yet to see similar gains. These farmers, the majority of whom are women, lack access to many of the tools needed to be successful, such as modern irrigation practices, crop management products, fertilizers, postharvest loss solutions, improved seeds, mobile technology, as well as access to information and extension services (Committee, 2011). Innovation in the Nigerian agricultural sector offers promises of improving farmers' lives, feeding and nourishing more of our population, and consequently, improving the political, ecological, and economic stability of the country. Through these tools and through much greater investment in agriculture, we can move toward more sustainably curbing global hunger and malnutrition around the world by dramatically increasing productivity yields, conserving food by substantially reducing postharvest losses and food wastage, giving farmers access to real-time information and services in the field, and even improving the nutritional content of foods.

The use of agricultural technologies not only affects the rate of increase in agricultural output, but also determines how the increase in agricultural output impacts on poverty levels and environmental degradation. Therefore, the focus of recent research has been to find better agricultural practices, discovering new strains of crops, improvements of land, soil and water management practices (Agriculture, 2015; Mwangi and Kariuki, 2015). However, the only way for smallholder farmers to benefit from these research station technologies is if they perceive them to be appropriate and proceed to implement them on their farms.

Increased agricultural productivity, technology adoption rates, and household food security and nutrition can be achieved through improved agricultural practices, expansion of rural financial markets, increased capital and equipment ownership by rural households, and development of research and extension linkages (von Braun, 1999). Increased technology development and adoption can raise agricultural output, hence improved household food intake. Improved food intake can also improve the functioning of the human body and the performance of a healthy, normal life which will increase work output (Nwankwo, 2017). Therefore, increase accessed to developed technology may result in high rate of adoption of the technologies and thus reduced labour demands.

The Nigerian agricultural sector is predominantly dominated by resource-poor farmers who still practice the traditional or subsistence agriculture in which simplest traditional tools are being used. The output and productivity are low, capital investment is minimal, while land and labor constitute principal factors, thus culminating in the “law of diminishing return” – high labor and input applications but low returns. According to Galadima (2014) an enormous gap exists between available knowledge of improved technology and actual practice which has had considerable negative effects on food production.

Farmers in Nigeria are faced with some difficulties in using the required mechanical tools to implement mechanization on their farms and processing of their produce. Some of these difficulties are policy and monetary in nature (namely, government support policies and access to bank loans), and some other difficulties are structural and infrastructural in character (such as subsistence farming, nature of the land: topographical and geometrical shapes and small land holdings). In addressing some of these challenges, NCAM has developed various types of adoptable and adaptable agro-processing technologies such as cassava processing technologies, rice processing technologies, integrated farm projects, etc., and rendering services such as land clearing services, tractor hiring services, etc. to ease the suffering of farmers and increase their productivity. Agricultural innovations are basically aimed at growing the various native crops to each diverse local area within the world's ecosystem. This diversity requires different agricultural technologies suitable for each local area. In this view, much effort have been made by NCAM to develop machines for specific agricultural production in each local area, and those attempts have been to a large extent successful in meeting demands of each rural farmer. However, it is essential to form an interrelated system in which researchers, developers, manufacturers, and distributors are engaged in collaborative efforts to solve farmers’ problems locally (Rasouli, et al. (2009).

The National Centre for Agricultural Mechanization (NCAM) in her stride to improve the livelihood of farmers and ensure food security in the country has made tremendous efforts in Research and Development of simple agricultural technologies (Faleye et al., 2012). Also, from the study by Mohammed et al. (2014) carried out in Ifelodun Local Government Area of Kwara State, Nigeria with the objective promoting the adoption of NCAM agricultural processing technologies among farmers in the neighboring communities. These technologies have the potential to enable stakeholders to improve their yields and income, food security, and participation in the economy. Since the majority of the world's poor live in rural areas, lack of connection to information technology have limited access to many goods and services (Mgbenka et al., 2015). In this perspective, there is need to assess the determinants poised against rural farmers in accessing NCAM proven technologies.

2. METHODOLOGY

The study was conducted across the six geo-political zones where NCAM Processing Centers were established. A multi stage sampling technique was adopted for this study. Six states were purposively selected across the six geo-political zones; Kwara (North-Central), Akwa-Ibom (South-South), Kebbi (North-West), Borno (North-East), Ogun (South-South) and Imo (South-East). In the second stage six (6) communities each were randomly selected due to their proximity to the established processing centers making a total of 36 communities selected for the study. A total of 200 questionnaires were administered within the 36 communities using convenience sampling technique.

Data collected was analyzed using descriptive statistics presented in frequency table while multiple regression analysis was used to assess the determinants in accessing NCAM proven technologies across the six geo-political zones.

3. RESULTS AND DISCUSSION

Socio-Economic Characteristics of the Respondents

Table 1. Socio-Economic Characteristics of the Respondents

VARIABLES	FREQUENCY (N=200)	PERCENTAGE
Gender		
Male	148	74.0
Female	52	26.0
Age		
<20	6	3.0
21-30	24	12.0
31-40	72	36.0
41-50	84	42.0
>50	14	7.0
Marital Status		
Married	154	77.0
Single	28	14.0
Widowed	18	9.0

Household Size		
≤3	62	31.0
4-6	108	54.0
7-10	30	15.2
Educational Status		
No formal Education	21	10.5
Arabic/Islamic Education	59	29.5
Adult Education	42	21.0
Primary Education	41	20.5
Secondary Education	21	10.5
Tertiary Education	16	8.0
Occupation		
Farming	73	36.5
Artisans	24	12.0
Trading	60	30.0
Civil servant	31	15.5
Student	12	6.0
Experience		
≤2years	15	7.5
3-5years	42	21.0
6-8years	41	20.5
9-11years	49	24.5
≥12years	53	26.5
Membership of Cooperative Society		
Yes	168	84
No	32	16
Source of Information		
Undecided	23	11.5
Media	29	14.5
Friends & family	52	26.0
NCAM staff	86	43.0
Extension agent	10	5.0
Patronage on NCAM Established Processing Centers		
Yes	171	85.5
No	29	14.5

Table one shows that majority of the respondents were male (74%), Singh et al. (2014) reported that gender affects technology adoption since the head of the household is the primary decision maker and men have more access to and control over vital production resources than women due to socio-cultural values and norms. Also, about 90% of the respondents were between age 21 and 50 years old, this shows that majority of the respondents belong to the active segment of the population, while the remaining 10% belong to the aged group. This age group has tendency of having positive impact in accessing NCAM proven technologies by farmers in the study area. This age category is in line with those Solomon et al. (2012) referred to as economically active groups. About 77% 0f the respondents are married; this imply that farmers would likely place premium attention to NCAM processing technologies because of the awareness on their part that they have more responsibilities to attend to.

The distribution of household size among the respondents showed that majority of them (54.0%) had between 4 and 6 people per household. The respondents with household size ≤ 3 is 31.0% while that of between 7 and 10 had the lowest (15.2%). This is implied that respondents have a relative large family. A substantial proportion of the respondents (10.5%) had no formal education. Those with primary, Arabic, adult and secondary education constituted the highest percentage (81.5%) of the respondents. Only a small fraction of the respondents (8%) had post-secondary education. This supports the findings of Simpson and Owens (2003) who stated that the literacy level of farmers enhances the rate of adoption of improved technology. Majority (36.5%) of the respondents were full time farmers, 30.0% indicated trading to be their major occupation, while the remaining 33.5 % of the respondents were civil servants, artisans and students. This is in line with the findings of Obidike (2011), that majority of rural dwellers are farmers.

About 26.5% of the respondents had aboved 12 years of experience, 24.5% had between 9-11 years of experience, 20.5% had between 6-8 years of experience, 21.0% had between 3-5 years of experience, while 7.5% had below 2 years of experience. Long farming experience is an advantage for increased farm output and it may encourage rapid adoption of improved technology (Eze, 2014). The result in table 1 also shows that 84% (168) respondents in the study area belong to cooperative society while the remaining 16% (32) did not belong to any cooperative society. Majority of the respondents had experience as members of cooperative group which can facilitate understanding of agricultural information due to the interaction among themselves (Bello and Obinne, 2012). Information sources available to farmers on NCAM proven technologies in the study area indicated that most of the respondents (43.0%) received information from NCAM Staff. Other information sources available to respondents includes; electronic media (14.5%), family and friends (26.0%), extension agents (5%), while 11% of the respondents cannot decide the source of their information. This is line with the findings of Ipadelola, 2015 which says accessed information will assist farmers in the decision making process either to adopt or not adopt the available technologies. Therefore, a more targeted approach should be used in disseminating agricultural information to ensure that it reaches as many farmers as possible taking into account sources of information available to them. Respondents in the study area actively (85.5%) engaged in the usage of NCAM Processing Centers. This showed that NCAM has actively participated in improving the productivity of farmers in the study area. This result is in lines with the findings of Mohammed et al. (2014) and Faleye et al. (2012).

Multiple Regression Analysis

Table 2. Determinants of Access to NCAM Proven Technologies

Regression Analysis						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	-3.694	2.600		-1.421	.157
	Gender	-.145	.134	-.066	-1.083	.280
	Age of Respondent	-.044	.057	-.049	-.772	.441
	Marital status	-.037	.119	-.034	-.309	.758
	Membership of cooperative	2.716	1.219	1.300	2.229	.027*
	Household size	.034	.270	.024	.126	.900
	Educational status	.301	.048	.403	6.252	.000*
	Occupation	-.022	.078	-.037	-.281	.779
	Experience	-.095	.070	-.141	-1.354	.177
	Source of income	-.068	.214	-.031	-.319	.750

Source: Field survey
Significant at 1% and at 5% probability level respectively
*Significant
R^2=0.691
Adjusted R^2 = 0.608

Data in Table 2 show the determinants of access to NCAM proven technologies by respondents in the study area. The R square (0.691) value indicates the access to NCAM proven technologies by the determinants (socioeconomic and institutional characteristics of the respondents).

The determinant coefficient (adjusted R^2) amounted 0.608 meant that the variation of access to NCAM proven technology could be explained by the independent variables of gender, age, marital status, membership of cooperative societies, household size, educational status, occupation, experience and income amounted 60.80%, while 39.20% were explained by other factors that are not included in the model.

The result in Table 2 further shown that out of ten variables investigated, only two variables were found to be statistically significant in influencing the access of NCAM proven technologies. These include membership of farmers' group/cooperatives ($P< 0.027$) and educational status ($P < 0.000$). Membership of cooperative societies has positive influence ($t = 2.229$, $P = 0.027$) on the access to NCAM proven technologies by the respondents in the study area. Ayodele et al. (2016) showed that cooperative membership increases the adoption of improved agricultural technologies. Also, Abdulquadri and Mohammed (2012) affirmed that cooperative organizations created an appropriate avenue for demonstration of agricultural modern technologies to meet farmer's needs in agricultural production and processing. This also justifies the view of Abdullah and Samah (2013) that cooperative societies can serve as a vehicle in dissemination of agricultural technology. The result also implies that the respondents agreed to the fact that cooperative contribute to agricultural production. Therefore, frequent contact of NCAM researchers with members of farmer cooperative gave them the opportunity to learn more on the availability and use of new improved technologies developed by the Centre (Mohammed et al., 2014). In the light of this Kughur and Ortindi (2015) showed that frequency of extension contact with members of farmers cooperative to be the significant factors influencing adoption of agricultural technologies. Therefore, the positive impact of farmer's cooperatives is that an increase in their number will leads to more access to agricultural technology. Thus create an easy access for extension agents to contact a large pool of farmers at a particular place within the same period of time. Hence, farmers who have contacts with extension organizations are likely to hear about improved varieties and thus have more incentive to adopt these new agricultural technologies.

The Result also indicated that educational status of the respondents ($t = 6.252$, $P = 0.000$) had positive influence on the access to NCAM proven technologies in the study area. Hence, higher education allows farmers to make efficient adoption decision. This corroborate findings of Rahji (2014) who emphasized strong positive influence of education on adoption. This reveals that the more the number of years in school, the better the level of adoption of the technologies by the respondents, this is because the more the level of enlightenment, the better the willingness of the farmers to accept farming innovations. The farmers could easily understand the new technologies and are more willing to adopt than their illiterate counterparts.

4. CONCLUSIONS AND RECOMMENDATION

The willingness and ability of farmers to access the proven technologies developed by the Centre at the respective processing centers depends to a large extents on availability of information on the technologies. The findings in this study clearly shows that the socio-economic characteristics of the respondents is a major determinants in accessing agricultural technologies, whereby cooperative societies, household size, and educational status have positive relationship with access to information on agricultural technology hence leads to probably adoption of the technology. Therefore, there is need for more publicity of NCAM technology by further strengthen of NCAM extension services as proofed in the study that the respondents access more information on NCAM proven technologies through NCAM staff which is leading to improvement in farmers livelihood.

Therefore, based on this motive of increasing dissemination of information on NCAM proven developed technologies to the farmers, the following recommendations are suggested:

1. There is need for continuous publicity of NCAM proven developed technologies to create awareness among farmers and the general public;
2. There is need to strengthened the services of NCAM extension, as it has been proved in the study that majority of information about the Centre were sourced through NCAM staff;
3. There is need for farmers' adult education / enlightenment workshops (i.e agric show) to provide information on the technologies as it has been proved that education contribute immensely in accessing NCAM proven technologies. The workshops should be designed to increase their knowledge about the proven technologies developed by the Centre; and
4. Farmers should be more encouraged to form and actively participate in cooperative societies or social group to enable ease dissemination of information by extension agents to them at a particular time in a particular place.

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DETERMINANTS OF FARMERS ADOPTION OF SOIL DEGRADATION PREVENTIVE MEASURES IN ABIA STATE, NIGERIA

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ABSTRACT
This study examined the determinants of farmers adoption of soil degradation preventive measures in Abia State, Nigeria. Primary data used in this study were collected using questionnaire that was administered to 120 randomly selected farmers in the study area. Descriptive statistics and Ordinary Least Squares regression method were used in analyzing the data. The result of the study showed that the major causes of soil degradation in the study area were: deeply excavated subsoil and overburden with materials, extremely eroded due to deforestation and loss of biodiversity leading to attendant soil loss. The impact of soil degradation on the income of farmers showed that 82.8% of the farmers responded to poor soil fertility; 81.08% responded to low farm income; 70.2% on loss of crop output/fruit trees; 66.6% on loss of farmlands and forest biodiversity. The various measures adopted by the farmers for the prevention of soil degradation in the study area with the cost implications of such adoptions were the use of organic manure with total cost incurred as ₦777,100 and average cost of ₦9,963 per farmer; planting of leguminous/cover crop with corresponding total cost incurred as ₦380,750: use of inorganic fertilizer and planting of trees with the corresponding average costs by individual farmers as ₦15,869 and ₦8,225, respectively. The determinants of adoption of soil degradation adaptation measures were income, education level, farming experience, extension contact, and age. Inadequate knowledge on how to cope with soil degradation, and limited income were the major constraints in remediating soil degradation. The study recommended the need for agricultural programme that will involve educating and empowering farmers on reducing soil degradation activities, government intervention in the remediation of soil degraded areas as this will reduce the high cost incurred by farmers in the use of soil conservation techniques.

KEYWORDS: Adoption, Soil Degradation, Preventive, Measures

1. INTRODUCTION
Soil constitutes the foundation for agricultural development, essential ecosystem functions and food security and hence is key to sustaining life on earth (United Nations, 2013). Food and Agriculture Organisation (2015) defined soil as the natural medium for the growth of plants. Soil has also been defined as a natural body consisting of layers (soil horizons) that are composed of weathered mineral materials, organic material, air and water (Gomiero, 2016). The impact of human activities and natural phenomenon has led to the degradation of soil and impinges on its capacity to support life especially though agricultural production. Soil degradation is one of the most serious ecological and environmental problems in South East Nigeria (Kouelo *et al.*, 2015). FAO (2015) defined soil degradation as a change in the soil health status resulting in a

diminished capacity of the ecosystem to provide goods and services for its beneficiaries. Therefore, soil degradation represents a major threat to food production and environmental conservation, especially in tropical and sub-tropical regions. Soil degradation, therefore, refers to a broad spectrum of changes in soil characteristics because of natural or anthropogenic factors that alter their structure and quality, including deforestation and the removal of natural vegetation, agricultural activities, overgrazing, overexploitation of vegetation for domestic use, and industrial activities (FAO, 2015; DeLong *et al.*, 2015; Karlen and Rice, 2015).

Soil degradation can occur through the following processes: physical (i.e., erosion, compaction), chemical (i.e., acidification, salinization) and biological (i.e., loss of soil organic matter, loss of biodiversity) (Gomiero, 2016). The factors that determine the kind of degradation are as follows: soil inherent properties (i.e., physical, chemical), climate (i.e., precipitation, temperature), the characteristics of the terrain (i.e., slope, drainage) and the vegetation (i.e., biomass, biodiversity) (Lal, 2015; Okorafor *et al.*, 2017). The causes that lead to soil degradation are complex and can be of a different nature: biophysical (i.e., land use, cropping system, farming practices, deforestation), socioeconomic (i.e., institutions, markets, poverty), and political (i.e., policies, political instability, and conflicts) (Lal and Stewart, 2013; Barrett and Bevis, 2015; FAO, 2015).

The danger in the physical damages to soil that rages from structural degradation to actual loss of the soil through various processes, has continued to attract the interests of environmentalist. This may have consequences in the quality changes relevant to crop production arising from land degradation (Binie *et al.*, 2002). In the south east of Nigeria, the lands are highly susceptible to three common soil degradation including physical, chemical and biological (Uchegbu *et al.*, 2017). The physical involves removal of surface layers of soil through water erosion, destabilization of the aggregate structure in the surface soil that may give rise to cervices, landslides, deforestation through mass movement of sandy soil, cracks in the earth crusts that encourages run off water thereby widening the gulley that can result to deep land sliders (Okorafor *et al.*, 2017).

The overall effects of soil degradation pose a major threat to food security especially in poor regions. All the adverse impacts on agronomic productivity and environmental quality are respectively due to a decline in soil quality. FAO (2015) highlights that there is a strong positive correlation between soil degradation and poverty. Therefore, this study is very apt for Nigeria with burgeoning rate of poverty. Poverty in Nigeria is said to be mainly a rural phenomenon where up to 80% of the population live below the poverty line (Edoumiekumo and Karimo, 2014; Adigun *et al.*, 2015). Runsewe (2017) stated that Nigeria was projected to be the poverty capital of the world in 2018 according to the world poverty clock.

According to Nkonya *et al.* (2011) and Tesfaye (2017), the world's population is growing and is projected to exceed 9.2 billion by 2050 and in order to feed this growing population it will be necessary to boost the production of food. However, land degradation is extensively increasing, covering approximately 23% of the globe's terrestrial area, increasing at an annual rate of 5-10 million hectares, and affecting about 1.5 billion people globally (Gnacadja, 2012).

Programmes of soil restoration have become necessary to assist the soil to recover productivity. The adoption and investment in sustainable soil management is crucial in reversing and controlling land degradation, rehabilitating degraded lands and ensuring the optimal use of land resources for the benefit of present and future generations (Akhtar-Schuster *et al*., 2011). Adoption of these measures play critical role in increasing productivity, achieving food security, household income and poverty reduction through reducing soil erosion and improving soil fertility (Lal and Stewart, 2013; Zucca *et al*., 2014; Iheke and Nwaru, 2014).

From the foregoing rural dwellers depend solely on the soil for livelihood and soil degradation is a major threat to food security. Also given that adoption of measures aimed at preventing soil degradation would lead to reduction in poverty and increased productivity, this study examined the determinants of farmers adoption soil degradation prevention measures in Abia State, Nigeria. Specifically, the study identified the causes of soil degradation prevalent in the area; estimated the loss in income of farmers as a result of soil degradation; identified the various measures used by farmers in preventing or reducing soil degradation and the cost incurred; estimated the determinants of adoption of soil degradation adaptation measures; and identified the constraints of farmers to preventing soil degradation in the study area.

2. RESEARCH METHODOLOGY

This research was carried out in Abia State, Nigeria. The State is in the South-East region of Nigeria. It lies between latitudes of $4^0$40' and $6^0$14' North of the Equator and longitudes $7^0$10' and 8^0 10' East of the Greenwich Meridian. It has a population density of 580 persons per square kilometer and a population of 2,845,380 persons and projected population of 3,727,300 in year 2016 (National population Commission-NPC, 2006; National Bureau of Statistics, 2016) and occupies an area of about 6420 km^2 with about 2.6 percent of the country's population. It has an average population density of 364 persons per square kilometer with 63 percent of the people involved in agricultural production because of the rich soil which stretches from the northern to the southern part of the State and has an average household size of 6 persons per family (NPC, 2006). It has three Senatorial Zones namely: Abia North, Abia South and Abia Central, with 17 Local Government Areas, grouped into 3 Agricultural Zones which are Umuahia, Ohafia and Aba Zones.

The climate of the State is a tropical one and usually humid all year round, with two seasons, the rainy season and dry season. The State is low lying with a heavy rainfall of about 2400mm which is evenly distributed between months of April through October, while the dry season starts from November and end February/March. The rest of the state is moderately high plain. The state is located within the forest belt of Nigeria and the temperature ranges between 20^0C and 36^0C. As a result of the climatic condition of the State, Nigerian Environmental Study/Action Team (NEST) (2011) reports major environmental damage caused by heavier rains to include flood, erosion especially in Aba and Ohafia Agricultural Zones of the State. The major crops grown are maize, yam, cassava, rice, vegetables etc, while livestock includes goat, sheep, poultry, pigs, etc. Plantain, oil palm, cocoa and rubber are some of the cash crops produced by the people.

A multi-stage sampling technique was used for this study. The first stage involved the purposive selection of two Local Government Areas (LGAs) each from the three Agricultural Zones namely, Aba, Ohafia and Umuahia making it a total of 6 LGAs. The selection was based on the prevalence of soil degradation. In the second stage, 2 communities were randomly selected from the 6 LGAs, making it a total of 12 autonomous communities while in the third stage, two villages were randomly selected from each of the selected communities making a total of twenty-four (24) villages. In the last stage, five (5) farmers were randomly selected from each of the village to have a total of one hundred and twenty (120) farmers.

Data for this study were collected from primary source. Preliminary visits were made to the study locations before actual commencement of data collection. This helped the researcher to familiarize herself with the study locations and to pre-test the data collection instrument. Data collected using structured questionnaire and interview schedules were analyzed using descriptive and inferential statistical tools. The causes of soil degradation, the effects of soil degradation, the various measures used by farmers in preventing soil degradation and the constraints faced by the farmers towards preventing soil degradation respectively, were realized using descriptive statistics such as means and percentages. The determinants of adoption of soil degradation adaptation measures was realized using Ordinary Least Square regression analysis. The model is specified implicit as:

$$Y = f (X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}) \quad 1$$

Where Y is adoption score measured as Y = (U/V)*100, with U as the participatory score of the respondent household on the number of measure adopted and V being the overall score of all the measures adopted by the farmer; X_1 = sex (1 = male, 0 = female); X_2 = marital status (Married = 1; otherwise = 0); X_3 = age (years); X_4 = household size (number of persons living together); X_5 = farm size (ha); X_6 = educational level (years); X_7 = net farm income (naira); X_8 = farming experience (years); X_9 = extension contacts (number of visit); X_{10} = Number of soil degradation experienced, (number of occurrences); X_{11} = Membership of cooperative group (Yes = 1, otherwise = 0); and X_{12} = Topography of land (Dummy: plain/flat land= 1, sloppy = 0).

Four functional forms of the model namely, Linear, exponential, Double log and Semi log model were fitted and the best fit model chosen as the lead equation. The lead equation was chosen based on some statistical and econometric criteria such as number of significant factors, the conformity of the signs borne by the coefficients of the variables to *a priori* expectations, the magnitude of the coefficient of determination (R^2) as well as the significance of the F – ratio.

3. RESULTS AND DISCUSSION

3.1 Causes of Soil Degradation

The causes of soil degradation based on farmers opinion is presented in Table 1

Table 1. Distribution of farmers based on the opinion on the causes of degradation

Causes	Mean Score	Rank	Remark
Deeply excavated subsoil and overburden with materials.	3.58	1	Accepted
Loss of soil productivity and quality chemical due to processes	3.57	2	
Socio-economic factors e.g. tenure system, farmers' health status, poverty etc.	3.20	3	Accepted
Refuse dumpsites producing leaching	3.12	4	Accepted
Extremely eroded due to deforestation and loss of biodiversity leading to attendant soil loss/ structural decline of the soil	3.08	5	Accepted
Rain run-off due to land slope, terrain and landscape position	3.06	6	Accepted
Compaction of soil due to footpath or animal grazing	3.05	7	Accepted
Leaching/Salinization/Acidification	3.05	7	Accepted
Soil inherent properties from parent materials	2.71	8	Rejected
Lack of soil and crop management e.g tillage, drainage, use of organic or inorganic fertilizer	2.68	9	Rejected
Inappropriate land use/soil management and cropping systems	2.66	10	Rejected
Drainage density	2.61	11	Rejected
Grand mean	3.03		Rejected

Source: Field survey data (2019).

The mean ratings of the opinions of the farmers based on their perceived causes of soil degradation in the study area is presented in Table 1. Deeply excavated subsoil and soil overburden with materials and loss of soil productivity and quality due to chemical processes. erosion were ranked first and second as major causes of degradation. This reduces the productivity of the soil. According to Gomiero (2016) deeply excavated subsoil and overburden with materials, extremely eroded due to deforestation and loss of biodiversity leading to attendant soil loss which causes soil degradation can occur through physical and biological processes such as erosion, compaction, mining activities, loss of soil organic matter, loss of biodiversity.

Other causes of degradation as identified by the farmers were socio-economic factors e.g tenure system, farmers' health status, poverty etc; extremely eroded due to deforestation and loss of biodiversity leading to attendant soil loss; refuse dumpsites producing leaching; barren landscapes with little or no vegetation; compaction of soil due to footpath or animal grazing; leaching, salinization and acidification; rain run-off due to land slope, terrain and landscape position with mean scores greater than the 3.00 which was the cut-off mean. Lal (2015) reported some factors such as chemical process like acidification, salinization; because of some factors such as soil inherent properties (i.e., physical, chemical); climate (i.e., precipitation, temperature), the characteristics of the terrain (i.e., slope, drainage) and the vegetation (i.e., biomass, biodiversity) causes soil degradation. Some researchers Lal (2013); Ogwo and Ogu (2014); FAO (2015) reported that factors like biophysical (i.e., land use, cropping system, farming practices, deforestation), socioeconomic (i.e., institutions, markets, poverty), and political (i.e., policies, political instability, conflicts) are all contributing factors that cause soil degradation.

Observations from the study location and oral reports from farmers showed that erosion, sloppy terrain and landscape position, continuous cultivation of land due to scarcity of farmland were the major cause of degradation. In agreement to these findings Lal (2015) reported that poor management of agricultural land induces soil erosion that leads to reduced productivity (which must be compensated with the addition of fertilizers), or, in extreme cases, to the abandonment of the land. Intensive conventional agriculture makes soils highly prone to water and wind erosion, which worsen when situated on a slope. Pimentel and Burgess (2013) reported mild to severe soil erosion is possibly affecting about 80% of global agricultural land. Soil erosion has been estimated to reduce yields on about 16% of agricultural land, especially croplands in Africa and Central America and pasture in Africa (Wood *et al.,* 2000).

Compaction of soil due to footpath or animal grazing as reported by Lal (2015) is a worldwide problem and can reduce crop yield by 20% – 55%. Nutrient depletion is another significant process of soil degradation, with severe economic impact on a global scale. To cover the losses, more land would have to be converted to agriculture and more inputs used to replace the reduced soil fertility. Nnabude (1995) reported that refuse dumpsites can cause chemical soil degradation were associated with salinization, leaching, nutrient imbalance and fertility depletion. According to Ademoroti (1996), accumulation of toxic substances of industrial and urban origin could contribute to chemical soil degradation. He also reported that in some intensively cultivated areas where the use of fertilizers and pesticides are high, chemical soil degradation was due to nutrient leaching, resulting in groundwater pollution and eutrophication of lakes. Some socio-economic activities such as continuous cropping of land to earn a living, cutting down of trees for wood resulting to deforestation, are linked to the cause of soil degradation and decline soil fertility which affect soil productivity (Kouelo *et al.,* 2015), while Ehikwe and Ugwu (2013) opined that the heterogeneity of the different components of soil, the rotation of farm land at average rate of one and a half yearly periods against the five yearly rotation period considered safer that the first option in the south east has been a causative factor to soil degradation.

Factors that cause of soil degradation as shown in this study include the removal of surface layers of soil though water erosion which was prevalent in the study area, destabilization of the aggregate structure in the surface soil that may give rise to crevices, deforestation through cutting down of trees and mass movement of sandy soil. Others include, cracks in the earth crusts that encourages run off water thereby widening the gulley that can result to deep land sliders, the rotation of farm land at an average of two years leaves the bush without due fallowing process and sufficient length of time, the continuous cultivation of land which is very devastating as most lands do not grow trees but shrubs and the increase in bush burning that has been a remarkable threat to land that homes are even ravaged and devastated, affect crop output, income and livelihood of farmers

3.2 Effects of Soil Degradation

The result of the effects of soil degradation by the respondents is presented in Table 2.

Table 2. Distribution of farmers according to their responses on effects of soil degradation.

Perceived effects	Frequency	Percentage
Poor soil fertility	92	83
Loss of farmlands/forest biodiversity	74	67
Loss of crop output/fruit tress	78	70
Loss of occupation/means of livelihood	42	38
Low farm income	90	81
Increase cost on soil remediation	65	59
Increase in subsistence cropping system	70	63
Increase in poverty status of farmer	73	66
Rural to urban migration	40	36
Change from farming to other occupation	54	49

Source: Field survey data (2019).

Table 2 showed that 83%, 81%, 70%, 67%, 66%, and 63% of the respondent noted that poor soil fertility, low farm income, loss of crop output/fruit trees, loss of farmlands and forest biodiversity; increase in poverty status of farmer, increase in subsistence cropping system, respectively were the result of soil degradation, while 59%, 49%, 38% and 36% indicated increase cost of soil remediation, changing from farming to other occupation, loss of occupation/means of livelihood and rural to urban migration as factors that resulting from soil degradation.

Most farmers interviewed perceived a decline in soil fertility, loss of farmlands, and crop yield. This decline in soil fertility and consequently of crop yields was most important indicator of soil degradation mentioned by farmers in the study affecting their income. This agrees with the study of Baba (2017) who reported similar situation in his study location (Kano State). Soil degradation in these sites has negative impacts on the communities due to diminishing level of soil fertility, loss of farmlands and forest biodiversity. These negative impacts have led to loss of arable farmlands, occupation, and means of livelihood with attendant economic hardship, and consequently increased rural-urban migration in the area.

The population structure during study location visits for the collection of data showed that the villages consisted more of aged people and children, indicating that the young people have migrated to the cities. Ehikwe and Ugwu (2013) reported that the immediate impact of soil or land degradation is the abandonment by members of the communities, forcing automatic or emergency migration on the people or their means of livelihood. This implied that soil degradation had a negative impact on their income which could affect their livelihood negatively. From the result of the study, farmers have their own perception in evaluating the impact of soil degradation affecting their income levels.

The findings are results in consonance with Bekele and Drake (2003); Gebremedhin and Swinton (2003). They noted that soil degradation is perceived by farmers through soil erosion and soil fertility depletion to affect their income and output, while Awoyinka *et al.* (2005) reported that 69% of the farmers experienced a low level of crop loss to soil degradation as a result of erosion. According to FAO (2015), soil degradation represents a major threat to food production and environment conservation, especially in tropical and sub-tropical regions (where most of the future population growth will take place). The negative impacts have led to loss of occupation and means of livelihood, income, and consequently increased rural-urban migration especially the young people. These negative impacts if not checkmated could increase soil bulk density, soil infertility, reduce soil porosity and infiltration of water into the soil as well as increase flooding and surface runoffs with attendant gully erosion.

3.3 Measures Used by Farmers in Preventing Soil Degradation and Various Cost Incurred

The result on the measures used by farmers in preventing soil degradation and cost incurred is presented in Table 3. The result showed the various measures adopted by the farmers for the reduction or prevention of soil degradation in the study area alongside the cost implications of such actions. Majority (70.2%) of the farmers adopted organic manure (poultry faeces, animal dung etc) with total cost incurred as ₦777,100 and average cost of ₦9,963 per farmer, followed by 65.7% of the farmers that adopted planting of leguminous/cover crop and corresponding total cost incurred as ₦380,750 while 41.4% and 36.04% used inorganic fertilizer and planting of trees with the corresponding average cost incurred by individual farmers as ₦15,869 and ₦8,225, respectively.

About 40.54% of the farmers adopted drainage construction and flood barriers and construction of diversion ditch with corresponding total costs incurred as ₦234,000 and ₦246,000, respectively. On the other hand, liming and water harvesting recorded the least in terms of adoption as only 14% of the farmers adopted them with the attendant costs of ₦85,600 and ₦26,000, respectively. Result further showed that an average of ₦295,325 was the total cost incurred by the farmers in adopting soil degradation prevention/reduction measures. These findings are in line with the results of Ogwo and Ogu (2014) who reported the measures employed by rural communities to combat soil and land degradation impacts to be bush fallow system as a measure of soil remediation in the areas, use of sand filled bags, use of isolated clumps of bamboos, terraced farming, alley cropping as vegetation strip and water harvesting practices, prevention of farming within specific distance (about 300m) from gully and the use of stones arranged to prevent flooding as the major remediation measures in the areas.

Table 3. Distribution of farmers based on the measures adopted in reducing soil degradation and the cost incurred

Measures adopted by the farmers	Frequency*	Percentage	Cost incurred (₦)
Using sand filled bags and stones to prevent flooding and as erosion control measure	43	38.74	131400
Crop rotation	66	59.46	255000
Planting of leguminous/cover crop	73	65.77	380750
Use of organic manure (poultry faeces, animal dung etc)	78	70.27	777100
Use of inorganic fertilizer (e.g NPK)	46	41.44	730000
Use of mulching	42	37.84	46500
Planting of trees	40	36.04	329000
Mixed farming	44	39.64	338000
Liming	14	12.61	85600
Multiple cropping	52	46.85	539000
Water harvesting	14	12.61	26000
Bush fallow	54	48.65	113000
Prevention of farming within specific distances from gullies	18	16.22	25000
Drainage construction/flood barriers	45	40.54	234000
Use of improved varieties of crops	44	39.64	462500
Water harvesting in catchment pits	22	19.82	142000
Construction of diversion ditch	33	29.73	246000
Construction of ridges across slopes	49	44.14	455000
Average	**43.17**	**38.90**	**295,325**

Source: Field survey data (2019). * Multiple responses recorded.

Ehikwe and Ugwu (2013) reported that long-term remediation of degraded soils was only by vegetation establishment through colonization of soil flora and fauna that would induce ecological succession. This could suggest why 36.04% of the farmers practised afforestation. As reported by Obalum *et al.* (2012) vegetation establishment would increase both the structural and functional dimensions of the ecological system. Survey carried out in the study areas indicated that the sites were extremely eroded due to deforestation and the attendant soil loss and productivity. These sites were located at Isukwuato, Bende and Ikwuano LGA, Abia State.

Majority of the farmers also adopted the use of organic and inorganic fertilizers, planting of leguminous crops. However, efficiency of organic or inorganic fertilizer in an eroded soil where the physical properties are degraded alongside chemical nutrients depletion depends, to a large extent, on the dynamic relationship between the level of harm done to the soil's physical condition and the level of progress made in the difficult task of improving it as reported by Ngwu *et al.* (2005), Adama and Quansah (2009) and Obalum *et al.* (2012).

Some situation of soil degradation needs a combination of carefully selected, suitable management practices depending on the shape of the yield reduction function. In Nigeria, for instance, research evidence from eroded alfisols suggests that, rather than inorganic fertilization, application of poultry manure and fallowing with various grass and leguminous species for two years, could improve the soil physicochemical properties and productivity (Salako *et al.*, 2007; Igwe, 2011).Using the study by Oyedele and Aina (1998)in southwestern Nigeria as a reference point, Lal *et al.* (2003) stated that soil chemical properties can account for over 75% of the variation in the yield from eroded soils in Sub Saharan Africa. Thus, soil degradation caused by erosion-induced short-term decline in productivity is more easily compensated by inorganic and/or organic fertilization and supplemental irrigation, drainage construction etc. as opposed to long-term decline in productivity.

3.4 Determinants of Adoption of Measures of Preventing Soil Degradation

Result of the regression estimates of the determinants of the adoption of soil degradation preventive measures is presented in Table 4. The exponential functional form was chosen as the lead equation with respect to econometrics and statistical criteria in terms of the number of statistically significant variables and the significance of F-ratio. The coefficient of determination ($R^2 = 0.620$) showed that 62% of the variations in the farmers adoption level of soil degradation preventive measures was explained by the independent variables ($X_1 – X_{10}$) investigated. The F-ratio which determines the overall significance of a regression model is statistically significant at the 1% level, implying that the model is adequate for further analysis. This implies that the independent variables jointly exerted great influence on the level of adoption of soil degradation preventive measures.

Table 4. Determinants of adoption of measures used in preventing soil degradation

Variable	**Linear**	**Exponential**+	**Double log**	**Semi-log**
Intercept	169.589	10.096	8.666	5.083
	(5.11)***	(12.31)***	(3.34)***	(2.23)***
Sex (X_1)	69096.750	0.422	0.476	100161.100
	(1.24)	(1.53)	(1.70)	(1.81)
Marital status (X_2)	-18903.020	0.575	0.590	12.956
	(-0.29)	(1.78)	(1.76)	(1.13)
Age (years) (X_3)	-0.005	-0.000	-0.095	-39.273
	(-2.86)***	(-2.90)***	(-3.39)***	(-3.29)***
Household size (X_4)	-8714.774	0.286	0.098	-4.235
	(-0.64)	(0.42)	(0.24)	(-0.42)
Farm size (X_5)	85239.300	0.271	0.059	-0.000
	(1.99)*	(1.19)	(0.80)	(-2.90)***
Educational level (X_6)	9287.135	1.332	0.272	22.423
	(1.41)	(5.92)***	(3.32)***	(1.87)
Net farm income (X_7)	-0.001	0.154	0.0770	-16.861
	(-0.06)	(1.85)*	(4.10)***	(-1.53)
Farming experience (X_8)	6055.290	34549.730	0.125	80920.590
	(1.78)	(2.34)**	(2.25)***	(1.57)
Extension contact (X_9)	1590.400	26.404	0.115	5.189
	(2.28)**	(2.86)***	(2.76)***	(2.14)**
Number of soil degradation	-46318.620	24.217	5.653	-79380.890
experienced (X_{10})	(-0.68)	(1.83)*	(3.41)***	(-1.15)
R – square	0.536	0.620	0.544	0.583
Adjusted- R square	0.455	0.576	0.458	0.536
F – ratio	7.50***	8.71***	7.56***	7.64***

Source: Field Survey Data (2019). ***, ** and* Significant at 1%, 5% and 10%, respectively. Figures in parentheses are the t-ratios. +Lead equation

The coefficient of age was negatively signed and highly significant at 1% alpha level implying an inverse relationship with use level of soil degradation preventive measures. This is suggestive of the fact that the older the farmer, the less the wiliness to adopt new soil degradation preventive practices. This is because older farmers are less receptive and more conservative to try new and improved farm techniques and are more risk averse. This is in agreement with the result of Okoye *et al.* (2007) that increasing age would make a farmer to be less energetic to work in the farm. Nyssen *et al*. (2009) reported that whereas old people responded better to participate with full interest, while young age farmers were more motivated to participate by the economic reward obtained from participation.

The coefficient of educational level was positively signed and statistically significant at 1% level. This is in line with *a priori* expectation as educated farmers are flexible and can adopt good changes and new improved soil degradation preventive technologies that can enhance their productivity and income. Thus, the more the level of enlightenment, the better the willingness of the farmers to accept farming innovations. This agrees with the findings of Adégnandjou and

Dominique (2018) that improving education and disseminating knowledge is an important policy measure for stimulating local participation in various natural resource conservation and adaptation measures. Contrary to the result obtained in this study Clay *et al.* (1998) found that education was an insignificant determinant of adoption decisions.

The coefficient of farm income was also positively signed and significant at 10% alpha level. This agrees with the findings of Tsefaye (2016), that income gives financial leverage to farmers with the adoption of new technologies. This implies that income encourages the adoption of improved technologies and preventive measures. On the other hand, increase in adoption of improved soil degradation preventive measures could result in increase in yield as well as accruable income. Moreover, International Institute of Tropical Agriculture (IITA, 2009) indicated that economic viability of a technology determines the extent of the adoption. This is because farmers are always ready to adopt any measure or technology that will increase their income from the farm. Equally, the adoption of a given technology or adaptive measures requires some financial commitments. An increase in farm income will enable the farmers to meet these commitments, thereby increasing adoption level.

The coefficient of farming experience was positively signed and statistically significant at 5% alpha level and positively related to adoption of soil degradation preventive measures. It shows that a unit increase in the years of farming experience will lead to an increase in the adoption level of soil degradation preventive measures. This implied that the more experienced a farmer in soil degradation and its effect on crop production, increase of positive attitudinal responses in carrying out activities that will prevent soil degradation. This is in consonance with the results of Frank (2012) and Akeem (2014). Iheke (2010) observed that the longer the years of farming experience, the more efficient the farmer becomes because the number of years a farmer has spent in the farming business may clearly give an indication of the practical knowledge he has acquired. This is an advantage in adopting soil degradation preventive measures will help to boost production in any pre-determined period of farming business.

The coefficient of extension contacts was positively related to the adoption level of soil degradation preventive measures. This implies that the more the number of extension contacts the farmers had, the higher their level of adoption of soil degradation preventive measures and vice versa. In agreement with the study of Iheke and Nwaru (2014) who reported that extension contact provides room for training of farmers which enhances their ability to understand, evaluate and adopt new production techniques which increase soil productivity. Contrary to the result of this study on extension contact, Akeem (2014) reported that there could be negative influence on the participation of extension activities in reducing farmers' attitude in preventing soil degradation because of the quality of the extension service and the areas of priority on which the extension services are based.

The coefficient of number of soil degradation experienced was positively related to the adoption of soil degradation preventive measures. As noted by Frank (2012) and Carlos and Sang (2015) that the knowledge of soil degradation and number of soil degradation experienced by farmers would enable them adopt indigenous coping strategies so as to allocate and utilize resources more efficiently to increase production and farm output.

3.5 Constraints Encountered by Farmers in Preventing Soil Degradation

Constraints encountered by farmers in preventing soil degradation in the study area is presented in Table 5. Constraints encountered in degraded soil remediation among farmers according to the highest ranking were inadequate knowledge on how to cope with soil degradation, limited income, non-availability of credit facilities, high cost of fertilizer/liming materials, and inadequate research extension–farmers linkages. Others include limited trainings on management of soil degradation, non-availability/high cost of inputs, varying topography of farm environment and multiple local cropping patterns among farmers.

Table 5. Constraints encountered by farmers in preventing soil degradation

Constraints	Frequency*	Percentage	Rank
Inadequate knowledge on how to cope with soil degradation	78	70.27	1
Limited income	77	69.37	2
Non-availability of credit facilities	68	61.26	3
High cost of fertilizer/liming materials	66	59.46	4
Inadequate research extension –farmers linkages	65	58.56	5
Limited trainings on management of soil degradation	64	57.66	6
Non-availability/high cost of inputs	62	55.86	7
Varying topography of farm environment	55	49.55	8
Multiple local cropping patterns among farmers	50	45.05	9
Land management problems	49	44.14	10
Non-availability of farm inputs	46	41.44	11
Traditional belief/practice	44	39.64	12
High cost of organic manures	43	38.74	13
Unawareness of soil degradation of farmland	42	37.84	14
Farmers' apathy towards soil degradation control	39	35.14	15

Source: Field survey data (2019). * Multiple responses recorded.

Nwokoro and Chima (2017) opined that these constraints affect the participation of rural farmers in the conservation and remediation of environmental resources while Baba (2017) reported that, soil and land degradation remediation is related to their socio-economic circumstances and to ecological characteristics of their environment, particularly rainfall. Scherr (1999) identified various factors influencing the pace of soil transformation which include: farmer knowledge about the degradation of the degrading resource, incentives for long-term investment, capacity to mobilize resources for land investment, level of economic returns to such investment, factors affecting the formation and function of local groups to help mobilize resources and coordinate landscape-level change.

It is necessary that rural people be empowered through environmental education on resource management, in order to revitalize important traditional resource management practices which they depend on for livelihood. However, Munasinghe (1993) argued that effective participation of local farmers in resource management could be achieved through what he termed 'conservatism' and 'primary environmental care'. These two concepts observe the ways rural people could initiate soil management practices of their own by revitalizing traditional methods of this resource management in their agricultural activities, bearing in mind, the consequences of unsustainable agricultural practices on food security. However, this can only be achieved if appropriate actions are put in place to tackle these constraints inhibiting effective soil resource management in agricultural activities in the rural settings.

According to Jouanjean *et al.* (2014) improvement of the livelihood of the poor and rural farmers will invariably improve attitudes limiting the wasteful usage of their immediate environmental resources. Lack of knowledge of soil degradation on the part of the rural farmers increases chances of indiscriminate use of immediate soil resources. Hence, it should be the priority of government agencies to ensure that environmental education reaches to poor farmers in the rural areas.

4. CONCLUSION AND RECOMMENDATIONS

Farmers in the study area identified deeply excavated subsoil and overburden with materials, extremely eroded due to deforestation and loss of biodiversity leading to attendant soil loss as the major causes of soil degradation. Poor soil fertility was reported by farmers as the major effect of soil degradation in the study area. The major measure adopted by the farmers for the prevention of soil degradation in the study area alongside the cost incurred for such adoption was use of organic manure (poultry faeces, animal dung etc) which was adopted by 70.2% of the farmers, with total cost incurred as ₦777,100 and average cost of ₦9,963 per farmer. The determinants of adoption of soil degradation adaptation measures were income, education level, farming experience, extension contact, and age. The major constraints encountered by farmers in preventing soil degradation was inadequate knowledge on how to cope with soil degradation. Based on the findings of this study, there is need to educate and expose farmers to new technologies and programmes such as climate smart agriculture adaptation programmes and innovations that are easy to practice, cost effective and ensure soil and nutrient conservation for improved productivity.

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DEVELOPMENT OF A MEDIUM SCALE MOTORIZED DRY BEAN SEED DEHULLING MACHINE

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ABSTRACT

The need to dehull seeds such as maize, beans, etc for further processing for various food products has become imperative. Thus, this work aimed at developing and fabricating a dry bean seed de-hulling machine using abrasive disc design concept. The de-hulling mechanisms utilizes eight abrasive discs attached to the shaft in the de-hulling chamber of the machine. The de-hulling machine was specifically developed for dry bean seed processing however, could also work for other seed such as maize, soya beans and guinea corn. The chaffs leave the machine through a slot created under the polishing chamber while the de-hulled seed fall through the seed outlet under the action of gravity into a bowl or sack placed under the polishing chamber. Preliminary evaluation revealed that the machine had output capacity of 1.04 ton per hour with overall efficiency of 83.60 %.

KEYWORDS: Development, Machine, De-hulling, Dry Bean Seed

1. INTRODUCTION

De-hulled bean seed is a product that is used for various delicacies in Nigeria, such delicacies ranges from Akara in Igbo language, Kosai in Hausa language and English language is known as bean cake, Moimoi and cooked milled de-hulled bean without oil commonly referred to as *Ekuru* in Yoruba language. Another is bean soup known as Gbegiri soup which is a delicacy in the consumption of cooked yam flour commonly referred to as Amala. These food products mentioned are widely consumed across Nigeria and some other countries of the world mostly in Africa.

Thus, de-hulling of dry bean seed become a major challenge. However this has not been adequately addressed as bean is commonly been de-hulled by soaking in water and thereafter rubbing the seeds against each other manually by hand, leg or pestle and mortar. This method is wet de-hulling where the product is difficult to store because of the moisture level of the de-hulled.

The need to encourage motorising dry de-hulling becomes imperative because it will save time as preparation is without going through rudiment of soaking in water. It will also create job opportunities through small scale industry. None the less de-hulling of bean seed has been from time immemorial; however, this study is looked at creating an indigenous way of coming up with a technology that can de-hull dry bean seed in a cheap and efficient method using locally available materials.

De-hulling involves removal of the fibrous seed coat that tightly envelops the cotyledons. In other words, de-hulling may be described as the efficient and complete removal of the outer layers enveloping the cotyledons from the kernel leaving a seed coat free cotyledon. Mortar and pestle, hand rubbing and grinding stone are used in the olden days to de-hull seeds, thereby giving room for a better way of de-hulling. There some attempts to motorise seed de-hulling resulting in the development of machines based on attrition and tangential abrasive de-hulling devices (Akintola, et al. 2018).

It has been suggested that as much as 33-5 0% of food grade protein will come from plant protein in the future (Bird, 1974). Dry edible beans provide an excellent source of protein and a balance of other essential nutrients to the diets of both developed and subsistent populations (Muggio, et al 1981). At the same time that consumption of vegetable proteins is expected to increase, U.S. per capita consumption of canned and packaged dry beans has continued to decline from 7.6 pounds per year in 1962 to 4.1 pounds per year in 1981. Whole beans require soaking and long cooking times. Canned beans, one of the first convenience foods, have become a staple but less promoted product on retail shelves.

A study by the National Science Foundation identified five potential areas for increasing the per capita consumption of dry beans, including the development of food products based on legumes (Adams et al., 1978). New technologies for altering the form of dry edible beans into specialty flours have been developed by the Protein Research Centre at Texas A&M University and tested at the Food Science and Human Nutrition Department at Michigan State University. Dry bean flour is a new product to the industry whose marketability and costs are not known. The aim of the study was to develop a motorized dry bean seed de-hulling machine to make dry bean seed product available with specific objective of reducing the drudgery in manual dry beans de hulling. This is towards enhancing commercial scale beans processing.

2. MATERIALS AND METHODS

2.1 Description of the Machine

The dry bean seed de-hulling machine can de-hull dry bean seed of different size. The machine consists of the following main parts: hopper, de-hulling chamber, drive shaft, polishing chamber, and frame as shown in Figure 3.

2.1.1 Hopper: The hopper of the machine has the length of 360 mm, 305 mm width and the height of 270 mm. It was made from a 2mm thick stainless steel sheet. The hopper unit is connected to polishing chamber as it accommodates the dry bean seed before gradually moving to the polishing chamber.

2.1.2 De-hulling Chamber: It has the length of 290 mm, 285 mm width and the height of 250 mm, the de-hulling chamber is in between the hopper and the polishing chamber it accommodates de-hulling mechanism made of up four abrasive discs attached to the shaft at equidistance, the shaft is connected to the big pulley of the machine which transmit power from R175 diesel engine with the aid of belt to the de-hulling chamber. After de-hulling the de-hulled dry bean seeds gradually moves to the polishing chamber.

2.1.3 Polishing Chamber: The polishing chamber is attached to the through chute under the de-hulling chamber with length of 465 mm made from stainless steel sheet and diameter of 300 mm, it houses the polishing mechanism made of up brushes which rob dehulled beans against the drum wall thereby polishing the de-hulled dry bean seed. Thereafter the polished seed moves out of the machine through the seed outlet and collected using bowl or sack.

2.1.4 Drive Shaft: The shaft has the length of 670 mm with diameter 30 mm. It is held by two pillow bearings from both sides, the shaft transmits torque and motion generated by prime mover to turn the de-hulling and polishing mechanisms.

2.1.5 Frame: The frame of the dry bean seed de-huller is 985 mm long, 1000 mm high and 430 mm wide. It supports and allows the body to rest firmly. Itis made from 45 x 45 mm angle iron.

2.2 Working Principle of the Machine

The dry bean de-huller is operated and powered by a R175 diesel engine. It is operated by loading a dry bean into the hopper further dropping by gravity into the de-hulling chamber. The de-hulling chamber has four abrasive discs attached to the shaft which perform the task of removing the coat that cover the bean seed by robbing the bean seed against the discs arranged equidistance from each other. The de-hulled bean moves into the polishing chamber where the seed would be polished and discharged through the seed outlet into a bowl or sack.

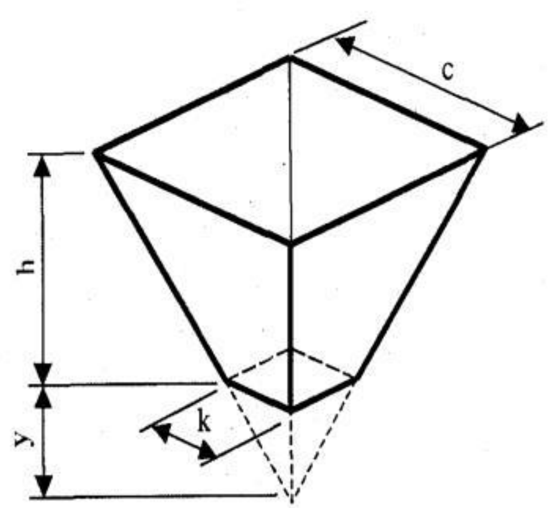
2.3 Design Considerations

In the design of the dry bean de-huller, many factors were considered to achieve an acceptable level of reliability and efficiency. These include: -

1. Physical properties of materials to be handle
2. Effective de-hulling, polishing and minimal loss of useful bean seed
3. Affordability, workability, availability and strength of materials used for fabrication
4. The quality of food to be handle, hence material that will not contaminate it.

2.4 Design Calculations

2.4.1 The hopper Design: The hopper was designed based on the volume of frustum of a pyramid. The volume of the frustum of a pyramid can be obtain as showed below:-



Volume of the big pyramid = $\frac{1}{3}c^2(h+y)$ (1)

Volume of the small pyramid = $\frac{1}{3}k^2y$ (2)

Volume of the frustrum = $\frac{1}{3}\left[c^2(h+y) - k^2y\right]$ (3)

where,

h is height of frustum {m}
y is height of small pyramid {m}
c is length of one side of the square base of the big pyramid {m}
k is length of one side of the square base of the small pyramid {m}

$$\text{Capacity of Hopper} = \frac{Volume\ of Hopper}{Volume\ of\ \text{dried bean seed}} \qquad (4)$$

2.4.2 The pulley:To determine the speed of the driven pulley, the relationship given by Ghupta and Khumi (2004) was adopted.

$$nd = ND \qquad (5)$$

where,

d is diameter of the small pulley {m}
n is speed of the small pulley {m/s}
N is desired speed of the big pulley {m/s}
D = desired diameter of the big pulley {m}

2.4.3 Belt Length:The length of the belt will be determined using Equation (6).

$$L = 2C + \frac{\pi}{2}(D_1 + D_2) - \frac{(D_2 - D_1)^2}{4C} \qquad (6)$$

where,

L is total length of the belt (mm)
D_1 is diameter of driven pulley (mm)
D_2 is diameter of driving pulley (mm)
C is distance between the centres of the two pulleys (mm)

2.4.4 The Belt Drive: Belts are used to transmit power in equipment. It requires close spacing and centre distance. It transmits power from motor to the shaft making the centre distance between motor and shaft to be adjustable. The twisting moment (T) was given as:

$$T = (T_1 - T_2)\ xR \qquad (7)$$

where,

T_1 is Tension in the tight side
T_2 is slack side of the belt
R is Radius of the pulley
Tension ratio for an open belt was calculated using Equation (8)

$$\text{Let } 2.3\ log\frac{T_1}{T_2} = \mu\pi \qquad (8)$$

Where: μ is the coefficient of friction between rubber belt and mild steel pulley given by 0.3.

2.4.5 The Shaft: The shaft was made from mild steel taking into consideration the Yield strength of the material, *Y and* Ultimate tensile strength, S_{ut} (Akintola et al., 2018).

2.5 Fabrication of Dry Bean Seed De-huller

Fabrication of the dry bean seed de-huller was carried out at the fabrication workshop of the Nation Centre for Agricultural Mechanization (NCAM), Ilorin. Figure 2 shows the detailed and dimensioned diagram of the produced dry bean de-hulling machine.

2.5.1 Hopper: It was constructed with stainless steel sheet of 2mm thickness, the length of the hopper is 360 mm, 305 mm width and height of 250 mm which are welded together to form the hopper in trapezoid shape.

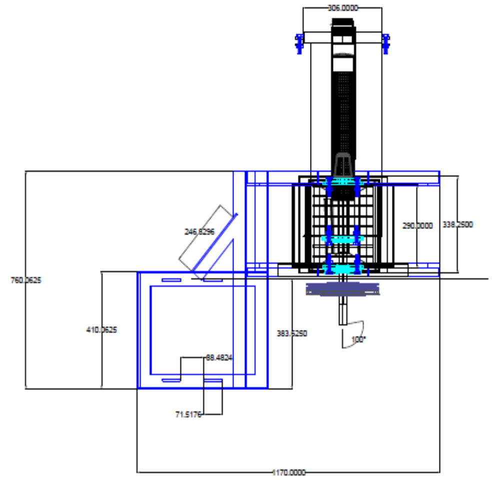
2.5.2 De-hulling chamber: The de-hulling chamber is one of the most important part of the machine. It is made from the same material as that of the hopper it has a length of 290 mm, 285 mm width and the height of 250 mm.

2.5.3 Polishing chamber: The polishing unit of the machine, was made from stainless steel sheet materials. It has a length of 465 mm and a diameter of 300 mm respectively. It is cylindrical in shape.

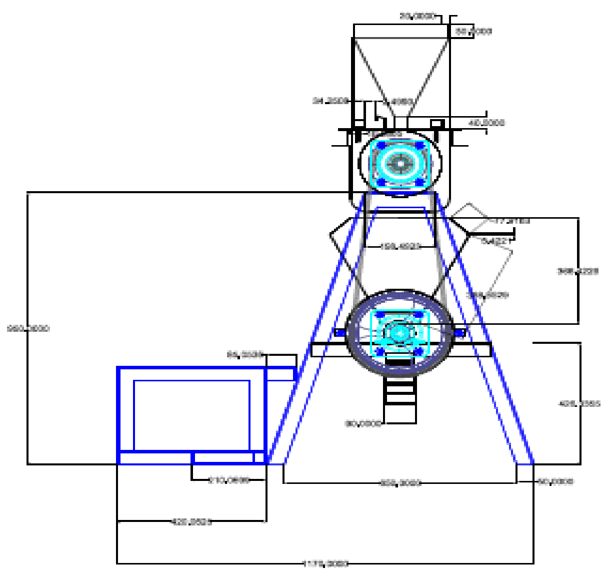
2.5.4 Shaft: The driving shaft is made from mild steel rod with the length of the shaft is 670 mm and the diameter is 30 mm.

2.5.5 Frame: This component part supports and hold other components of the machine, the frame is made of 45 x 45 mm mild steel angle iron. It has a length of 985 mm, width of 430 mm and height of 1000 mm.

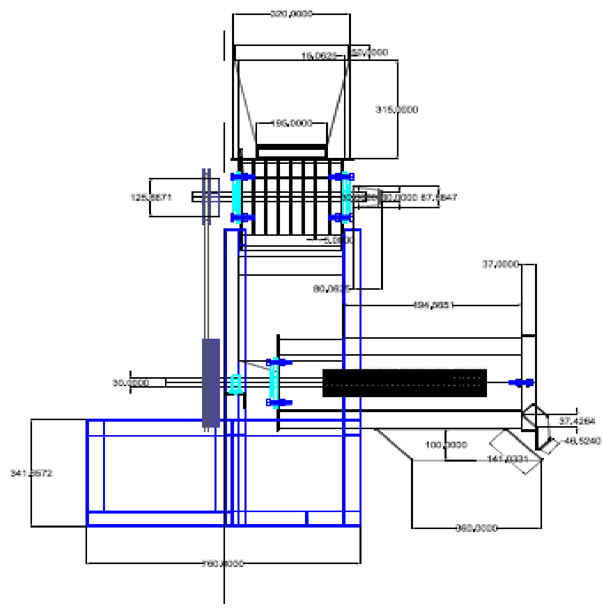
Fig. 1. The pictorial view of the machine



Plan



Front



End

Fig. 2. Third angle projection of the machine

S/No.	Components
1	Hopper
2	Dehulling Disc
3	Dehulling Chamber
4	Shaft Cap
5	Polishing Pulley
6	Bearing
7	Polishing Chamber
8	Through Chute
9	Dehulling Pulley
10	Belt
11	Shaft
12	Sieve
13	Frame

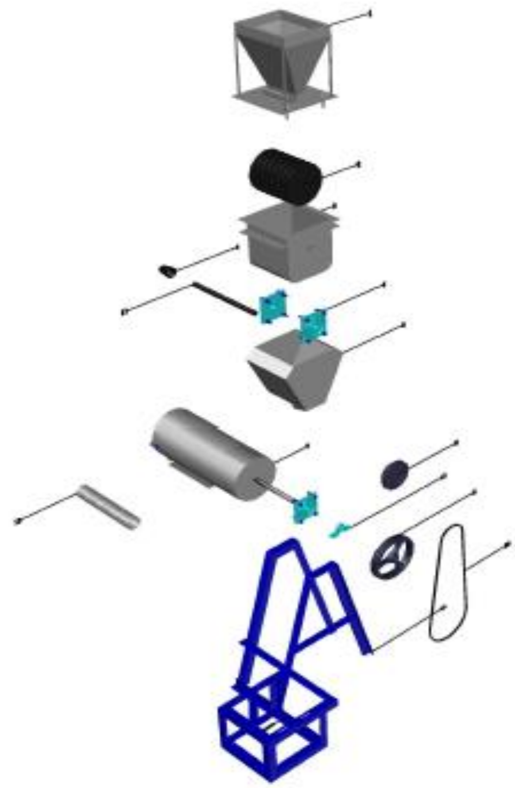


Fig. 3. Parts drawing of dry bean de-huller

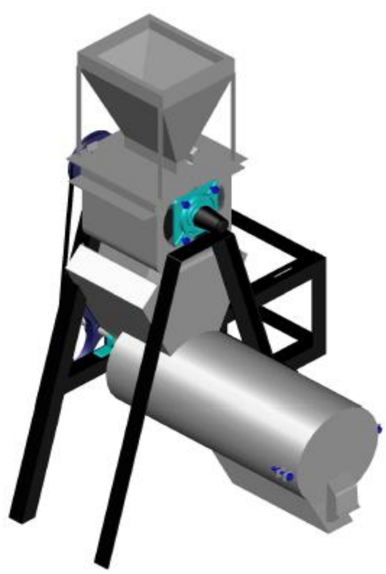


Fig. 4. Isometric view of dry bean de-huller

2.6 Performance indices

The dry beans de-hulling machine developed was subjected to a preliminary performance evaluation test. The beans variety used for the performance evaluation is black eyed peas (*Phaseolus vulgaris*) with a moisture content of 5.96 %. The test was carried out with 6kg, 4kg and 3kg of the test sample in three different batches. The performance indices that were used for the performance evaluation of the machine are; De-hulling efficiency (%) and Output capacity (kg/hr).

De-hulling efficiency - DE (%): This shows how efficiently the machine is de-hulling the sample. It was expressed as:

$$D_E = \frac{W_1}{W_1+W_2} 100 \qquad (9)$$

where,

W_1 is Weight of de-hulled seeds (kg)
W_2 is Weight of un-de hulled seeds (kg)

Output capacity-$O_{c(kg/hr)}$: This is the total quantity of seeds collected at the machine outlet per batch per unit time. It was expressed as:

$$O_c = \frac{W}{T}\left(\frac{kg}{hr}\right) \times 3600 \qquad (10)$$

where,

W is the total mass of seeds fed into the machine (kg)
T is time taken to de-hull the seeds (hr.)

3. RESULTS AND DISCUSSION

The developed machine was able to effectively de-hull dry bean seed and results of a performance test are shown in Table 1. This results revealed that the machine was able to deliver 1.04 ton of de-hulled dry beans in an hour with an average of 83.37 % recovery after dry de-hulling using the machine. It was also observed that the machine dry has a percentage recovered whole grain de-hulled beans of 22.61 % as shown in Fig. 5, while the percentage split de-hulled beans is 62.02 %. The percentage broken beans after de-hulling is 10.40%.

It was however observed that the chaff hulled from the beans contained some bean powder which was not in significant quantity. The breakages observed after de-hulling did not in any way affect the product quality because the beans whether whole, split or broken would be eventually milled into powder. The efficiency of the machine was 83.60%. The dry bean seed de-hulling machine is adjudged to save time and energy removing the drudgery in manual de-hulling methods. The components are suitable and are readily available in the market for effective maintenance.

Table 1. Data obtained from the evaluation of the dry bean seed de-hulling machine

Specimen	Initial weight (kg)	Final weight (kg)	Dehulling Time (min)	Speed (rpm)	Whole (%)	Split (%)	Broken (%)	Chaff (%)	D_{Eff} (%)	Oc (kg/hr)
A	6.00	4.91	15.00	14.00	19.82	68.30	9.05	2.83	81.70	1440.00
B	4.00	3.41	15.00	14.00	19.49	67.33	6.62	6.56	85.50	960.00
C	3.00	2.51	15.00	14.00	30.83	57.26	5.91	6.01	83.70	720.00
Mean	4.33	3.61	15.00	14.00	22.61	62.02	10.40	4.97	83.60	1040.00

(D_{Eff} - De-hulling efficiency; O_c - Output capacity)

Fig. 5. Sample of the whole De-hulled dry bean seed

Fig. 6. Sample of broken dry bean seed

Fig. 7. Sample of the split dry bean seed

Fig. 8. Sample of the chaff of De-hulled dry bean seed

4. CONCLUSION

From the results of the performance evaluation of the developed dry bean seeds de-hulling machine, effective seed processing by coat removal from the dry bean seed as well as chaff separation chaffs was achieved effectively. The machine was designed such that it can be easily fabricated and maintained by local fabricators and end users respectively. The developed dry bean seeds de-huller can be used by farmers in rural and urban areas to add value to beans production and processing and subsequently attract better pricing. This is also in addition to the fact that the de-hulled beans can be stored whole or milled for a long time. The Output capacity of the machine is 1.04 ton/hr with an efficiency of 83.60 %.

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WORKSHOP ETHICS: SELECTION AND HANDLING OF LABORATORY/WORKSHOP EQUIPMENT/TOOLS-A REVIEW

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ABSTRACT
This paper was articulated and information generated from relevant literature and reviewed works on the subject matter and gives the definitions of workshop, ethics and other keywords relating them and stipulating the functions of the workshop and the basic tools found in an agricultural mechanization workshop. Tool work habits and work ethics to be followed by the technician were discussed in some details including safe handling of tools, safety of the tools, tool maintenance and repair. Personnel and equipment safety and their guidelines for use were highlighted. Some of the different personnel safety equipment were discussed in some details. The information contained herein is presented in diagrammatic, tabular and textual format and will be beneficial to workshop technicians/technologists as well as the engineers supervising them. The main objective of the work is geared towards highlighting the safety issues in a standard agricultural engineering workshop and how to adhere to them to avoid workshop accidents and maintain a safe workshop environment.

KEYWORDS: Workshop, work ethics, tool work habits, human and tool safety.

1. INTRODUCTION

This paper on work ethics is meant to discuss what we are morally obligated to do in our workshops and laboratories to actualize the purpose for which they were established. It is important to understand what workshops/laboratories are and why they are established in order to utilize them appropriately, and safely. It has been said that there are different tools/equipment useable in different workshops/laboratories for different purposes. Thus there is the need to select them appropriately. The selection, in terms of size and purpose, is very important for the safety of the user, the tool/equipment and the workshop environment. Improper tool/equipment and wrong use of same could be hazardous, thus the import of this review. To commence the review, it is necessary to define the key terms to be discussed in this work.

2. DEFINITION OF TERMS

This section presents some definitions of the key words and terms used in this paper: workshop, ethics, laboratory, equipment/tool, workshop safety signs and signals to give insight on the general focus of the discussion.

2.1 A **workshop** may be a room, rooms or building which provides both the area and tools (or machinery) that may be required for the manufacture or repair of manufactured goods. It could also be a small establishment where manufacturing or handicrafts are carried on. Workshops typically contain workbenches, hand tools, power tools and other hardware. Along with their practical applications for repair of goods or do small manufacturing runs, workshops are used to tinker and make prototypes (Burress, 1997; Carlson, 2013; Flaherty, 2012).

Workshop may also mean a seminar, discussion group, a class or series of classes in which a small group of people learn the methods and skills used in doing something that emphasizes exchange of ideas and the demonstration and application of techniques, skills, etc. Matheney (2018) gave the following workspace per worker: open space workstation – (5.574 – 10.219 m^2); workshop group area – 7.432 – 9.290 m^2). For mechanical workshop the following dimensions are required in m^2: woodshop (11.6) (CTW, 2017); machine shop (500); surveying (94); fabrication and welding (48) etc.

2.2 Ethics are the moral principles that govern a person's behavior or the conducting of an activity. It involves systematizing, defending, and recommending concepts of right and wrong conduct. Of the three major areas of study within ethics recognized today: meta-ethics concerning the theoretical meaning and reference of moral propositions, and how their truth values (if any) can be determined; normative ethics, concerning the practical means of determining a moral course of action; and applied ethics, concerning what a person is obligated (or permitted) to do in a specific situation or a particular domain of action (Bartneck et al., 2021), we, in this paper, are to discuss applied ethics as it concerns the workshop and the laboratory.

2.3 A **laboratory** (colloquially called lab) is a facility that provides controlled conditions in which scientific or technological research, experiments, and measurements may be performed. Laboratory services are provided in a variety of settings: physicians' offices, clinics, hospitals, and regional and national referral centers (Bertholf, 2017), educational institutions as departmental or subject laboratories, centers of research, etc. Labs are classified based on the type of materials and contaminants handled and the hazards posed. Laboratory classifications can be further broken down by industry – Clinical/Biological, Animal, Chemical, Physical/R & D, etc. Their space requirements range from 10 – 500m^2 depending on the numbers of equipment and people required.

2.4 Equipment/tool is the set of articles or physical resources serving to equip a person or thing: such as the machinery, tools, etc. that are needed to do a job or the implements used in an operation or activity or needed for a special purpose. A tool is a device for doing work: an object designed to do a specific kind of work such as cutting or chopping by directing manually applied force or by means of a motor. It could be something used in the course of somebody's everyday work or job or the cutting part of machine: the cutting or shaping part of a power-driven device, e.g. the blade on a lathe. Different jobs require different kinds of equipment and tools (Nahmias and Olsen, 2015). Examples of equipment include devices, machines, tools, vehicles, etc.

2.5 Workshop Safety Signs and Signals. Workshop safety signs and signals refer to specific activities, objects or situations providing information or instructions about safety at the workplace, workshop or laboratory by means of a signboard, a safety color, an illuminated sign, an acoustic signal, a verbal communication or a hand signal (HMSO, 1996). These signs are essentially grouped into: prohibitive signs (do not do i.e. prohibiting behavior), warning signs (caution, danger), mandatory signs (must do i.e. action to be followed), safe condition signs (safest way to go, emergency exit/escape route, first aid) and firefighting signs (indicating fire equipment) as shown in Fig. 1.

Fig.1 Safety signs (HMSO, 1996)

2.6 Tool Work Habit. A good set of tools is your most important possession and no matter how fancy your tools are, they won't look after themselves. It's important to treat them like anything else you love - with care and attention (AMI, 2020). How and where you store them, and how you clean and re-store them after use defines tool work habit.

2.7 Work Ethics is one of these qualities that usually get over looked because of which people fail to understand its importance and how it can help one become valuable asset in the work place. Strong work ethics is an encapsulation of various qualities like professionalism, punctuality, loyalty, integrity, dedication, discipline, motivation, etc. (Gopakumar, 2020).

3. SELECTION OF TOOLS/EQUIPMENT

This is one of the foremost functions of effective workshop ethics as it determines the workability of the job to be done in terms of speed and efficiency. A great job may fail to be executable if the most appropriate tools/equipment combinations are not available. So it is vital to know what the best tools/equipment for a particular job is. Tool/equipment is designed to make a job easier and enable one to work more efficiently. If they are not properly selected, used and cared for, their advantages and benefits are lost. Regardless of the type of work to be done, one must have to choose/select and use the correct tools in order to do the assigned work quickly, accurately, and safely. Without the proper tools and the knowledge of how to use them, time is wasted, efficiency is reduced, and even injury may be sustained (Maaswinkel and Offereins, 1990). Finally, tools and equipment need regular maintenance, requiring good workshop facilities, a reliable supply of spare parts as well as qualified technical staff. The staff must know how to use the tools and how to operate the equipment in order to secure good work progress and the expected high quality results. It is also important that staff know the full potential, as well as the limitation, of the use of manual and work methods based on the equipment. This underscores the fact that tools and equipment require trained operators and supervisory staff who are proficient in their operation and maintenance. Since each job requires its set of tools/equipment and each specific workshop/laboratory should be serviced by specialized equipment/tools, it will be difficult to enumerate all the tools/equipment here. Suffice it to say that each trained technical staff in any workshop/laboratory should be able to properly choose and select his/her tools/equipment for any assigned job. Part of workshop ethics is the ability to properly select/choose the tool or the set of tools for a specified assignment (Fred's Appliance Academy, 2017).

According to True Value (2020), tools are particularly important in the workshop/laboratory. They are primarily used to put things together (e.g., hammers and nail guns) or to take them apart (e.g., jackhammers and saws). Tools are often classified as ***hand tools*** and ***power tools*** **(Fig. 2)**. Hand tools include all non-powered tools, such as hammers and pliers. Power tools are divided into classes, depending on the power source: electrical tools (powered by electricity), pneumatic tools (powered by compressed air), liquid-fuel tools (usually powered by gasoline), powder-actuated tools (usually powered by an explosive and operated like a gun) and hydraulic tools (powered by pressure from a liquid).

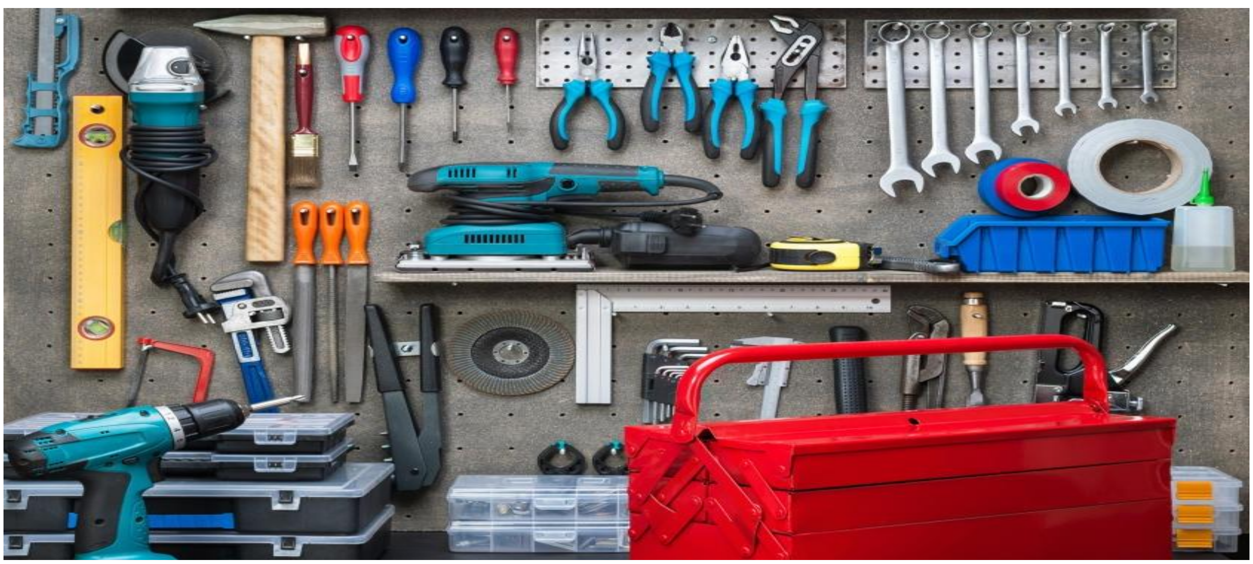

Fig. 2. Some hand and power tools. Source: True Value (2020)

3.1 Some common Tools in Agricultural Mechanization Workshop

The basic hand tools for agriculture: picks, shovels and spades, forks, hoes, hand operated sprayers, small hand tools, simple power tools, harvest tools, wheelbarrows, etc. These tools are used for making farm work easy. Most of them are manually used (Ajibola, 2019). The ones used in the agricultural mechanization workshop include: basic tools for metal cutting, basic striking tools, punches, taps and dies, power tools, portable pneumatic power tools, screw and tap extractors, pipe and tube cutters and flaring tools, screw drivers, etc. Their functions are briefly described below.

Basic tools for metal cutting: snips and shears, hacksaws, chisels, files, twist drills, wrenches (open-end, box-end, combination, box, socket, torque, adjustable, union nut, adjustable pipe, spanner, strap, setscrew – Allen & Bristol,), ratchet, handles (hinged, sliding T-bar, speed, socket), pliers (slip-joint, wrench, nose, combination, side-cutting, curved-needle, diagonal, duckbill, water-pump, groove-joint, wire-twister). Most of the engineering components such as gears, bearings, clutches, tools, screws and nuts etc. need dimensional accuracy and good surface finish for serving their purposes (Gunasegaran, 2018). That is the essence of these tools.

Basic striking tools: machinists' hammers (ball peen, straight peen, cross peen, soft metal or plastic, plain faced claw, riveting, bell-faced claw), mallets (carpenter's, rawhide, rawhide-faced, wooden, rubber), sledges (double face, cross peen, screwed-in inserted plastic face). Striking tools refer to tools that are used to strike or hit various objects, and they include hammers, chisels, punches, and drifts. Some of these striking tools are used with attachment devices such as nails and rivets (Washmuth, 2022).

Punches: a hand punch is a steel tool that is held in the hand and struck on one end with a hammer. There are several types: pin, center, prick, drift or starting, aligning, hollow shank gasket. Fourier and Fournier (1989) defined a punch is a tool used to indent or create a hole through a hard surface. They usually consist of a hard metal rod with a narrow tip at one end and a broad flat "butt" at the other. When used, the narrower end is pointed against a target surface and the broad end is then struck with a hammer or mallet, causing the blunt force of the blow to be transmitted down the rod body and focused more sharply onto a small area. Punches are used also to mark holes that are used as a guide for drilling.

Taps and dies: Taps and dies are used to cut threads in metal, plastics, or hard rubber. The taps are used for cutting internal threads, and the dies are used to cut external threads. There are many different types of taps. However, the most common are the taper, plug, bottoming, and pipe taps. For dies: there are the solid (square pipe, the rethreading), adjustable (open, screw, two-piece collet, two-piece rectangular pipe, round-split). Associate with these are the diestocks, die-collet, and tap wrenches, the adjustable die guide and ratchet diestocks as well as the tap and die thread sets (Keenan, 2005).

Power tools include: portable electric drills, three-jaw chuck and chuck key, portable grinder, electric disk sanders, portable electric sander, reversible electric impact wrench. A power tool is a tool that is actuated by an additional power source and mechanism other than the solely manual labor used with hand tools. The most common types of power tools use electric motors. Internal combustion engines and compressed air are also commonly used (*Nagyszalanczy, 2001).*

Portable pneumatic power tools: pneumatic chipping hammer, rotary impact scaler, rotary and needle scalers, rotary scaling and chipping tool, needle impact scaler**,** portable pneumatic impact wrench. These tools are powered by compressed air supplied by an air compressor. Pneumatic tools can also be driven by compressed carbon dioxide (CO_2) stored in small cylinders allowing for portability (Majumder, 1996).

Screw and tap extractors are used to remove screws and taps without damaging the surrounding materials. There are the straight tap and the spiral screw extractors (Gilles, 2003). Tap extractors are used to extract taps of different sizes; these sets include multiple extractors. Fingers on the extractor grip the flutes on a broken tap. They are used with a tap wrench to remove taps with straight flutes from the work piece.

Pipe and tubing cutters and flaring tools: pipe cutters are used to cut pipe made of steel, brass, copper, wrought iron, or lead; tubing cutters are used to cut tubing made of iron, steel, brass, copper, or aluminum, while flaring tools are used to make flares in the ends of tubing (single, double – die block, handle, adaptors. Pipe and tube cutters are hand-held tools or machines that use a rotating cutting wheel, blade, or other tool head to separate a long piece of tubular material into two or more parts. Pipe and tube cutters can be manually, electrically, pneumatically, or hydraulically powered. The type of cutter used depends on the material, diameter, and thickness of the pipe or tube (**RS Components, 2012).**

A **screwdriver** is one of the most basic of hand tools. It is also the most frequently abused of all hand tools. It is designed for one function only—to drive and to remove screws. There are many types: heavy duty, clutch tip, reed and prince, phillips head, torque-set, offset, ratchet and spiral. A screwdriver is classified by its tip, which is shaped to fit the driving surfaces—slots, grooves, recesses, etc.—on the corresponding screw head. Proper use requires that the screwdriver's tip engage the head of a screw of the same size and type designation as the screwdriver tip (*Encyclopedia Britannica, 2013)*.

4. TOOL WORK HABITS AND WORK ETHICS

As a workshop/laboratory technician or technologist or craftsman, there are certain ethics that must be followed concerning tools/equipment, even before you select them. The efficiency of craftsmen and the tools they use are determined to a great extent by the way they keep their tools. Safe and proper storage of tools define tool work habit, while appropriate behavior in the workplace define work ethics.

A. Tool work habit has to do with "having a place for every tool, and keeping every tool in its place" (Gleen. 2014; True Value, 2020).

1. Keep each tool/equipment in its proper stowage place – specialized toolboxes or pouches inside the tool room within the work station/center or workshop/laboratory.
2. Keep all tools in good condition – to protect them from rust, nicks, burrs, and breakage. Apply a light film of oil after cleaning to prevent rust on tools.
3. Keep tool allowance complete – when issued a toolbox, each tool should be placed in it when not in use. When the toolbox is not actually at the work site, it should be locked and stored in a designated area. An inventory list is kept in each toolbox to be used to account for the tools before and after use to prevent loss.
4. Use each tool for the job it was designated to do - each particular type of tool has a specific purpose. Using the wrong tool and improper use of tools when performing maintenance or repairs, may result in improper maintenance and cause damage to the equipment being worked on or damage the tool itself and even cause injury or death.
5. Safe maintenance practices - always avoid placing tools on or above machinery or an electrical apparatus. Never leave tools unattended where machinery or engines are running.
6. Never use damaged tools - a battered screwdriver may slip and spoil the screw slot, damage other parts, or cause painful injury. A gauge strained out of shape will result in inaccurate measurements.
7. Always keep hand tools clean and free from dirt, grease, and foreign matter. Oily, dirty, and greasy tools are slippery and dangerous to use. After use, return tools promptly to their proper place in the toolbox or on the rack.

Improve your own efficiency by organizing your tools so that those used most frequently can be reached easily without digging through the entire contents of the box. Avoid accumulating unnecessary junk.

B. Work ethic is a belief that work and diligence have a moral benefit and an inherent ability, virtue or value to strengthen character and individual abilities (Marek et al., 2014). Good work ethics is a tool that helps one become a valuable asset to an organization, which according to Gopakumar (2020) and Cruz (2022) include the following:

1. Punctuality – This one holds really high among necessary ethics at a workplace. It is said that 90% of success is showing up. Employee tardiness takes a toll not just on productivity but also on workplace morale signaling lack of commitment. Employees need to schedule their travel, meetings, deadlines etc. to be in the best practice of punctuality thereby minimizing bad elements like procrastination, delays and thereby increasing quality time spent at work.
2. Focus – Staying focused at the task in hand is one of the greatest challenges employees seem to face in today’s work environment especially when you have endless distractions around. Gossiping employees, cell phones, stress and fatigue, not prioritizing tasks are all a few examples of how one can easily lose focus at work. It is imperative to understand these situations and work hard on bringing back focus on priorities so as to end the day constructively. Manage time for a healthy work life balance.
3. Dedication – Dedication and staying focused sort of works hand in hand. You need to stay focused in order to be dedicated to the work you’re carrying out. Staying dedicated for a day keeps you on the right track, upholding the dedication for weeks and months puts you on the track for prolonged success in that it leaves you disciplined and resilient in the face of any obstacles in your way. You’re left with a sense of ownership which level once reached enables you to carry the task at hand to fruition.
4. Professionalism – One of the most important qualities is how to be a thorough professional. It shows a great deal about how serious an employee treats his work to be. It is about being capable of seeing the bigger picture, realizing the greater benefits of work, being a team player rather than being individualistic, being responsible for one’s actions, staying positive in times of difficulties and doing their job to the best of their abilities.
5. Personal improvement – A good employee is one who constantly upgrades and updates himself striving to be better than he was yesterday. An incessant hunger and a diehard passion drive him to excel not just at work but generally in life. Monotony tends to kill the growth drive in an employee and once this negative development begins to take form it leads to stagnation which is unpleasant. Therefore, a constant undying desire to improve helps a great deal in remaining focused and dedicated. Ask relevant questions when in doubt.
6. Initiative – Successful employees and great leaders are the ones who take initiatives and act on them. The ability to act independently is a crucial element of having a good work ethic —no matter how talented someone is if they need to be micro-managed, they’ll hold your team back.

7. Productivity – Maintaining all the above qualities would be of no use if ultimately the numbers don't show qualitatively and quantitatively, which all boils down to the term 'productivity'. All that matters to an organization at the end of it is its productivity which decides the results and profits for the organization. Candidates with a good work ethic find a way to get the job done, no matter the challenge, no matter how they are feeling that day.
8. Respect and achieve deadlines. Sticking to **deadlines** is a positive habit and trademark of successful people. Completing work on time shows that you're accountable and can nail tasks efficiently. Say no to procrastination.
9. Take criticism well. Don't frown at every criticism that comes your way. No one is perfect. Giving or receiving negative feedback is important for growth, and it's something you need from time to time. You should treat your employer as your career coach and learn to de-personalize the message. The feedback from an employee or your boss is to help you focus and become a better version of yourself.
10. Use a habit management app such as ClickUp. ClickUp is one of the most popular and highest-rated habit management apps used by productive teams across all domains. It's an all-in-one app that lets you set, manage, and track your personal projects and professional goals with ease.

4.1 Safe Handling of Tools

Craftsmen/technicians/technologists should be knowledgeable on safe procedures for working with tools. Tools can pose a safety risk when they are misplaced or improperly handled by workers. Some of the precautions to be taken when handling tools are, according to Crosbie (2020):

1. Workers should never carry tools up or down a ladder in a way that inhibits grip. Ideally, tools should be hoisted up and down using a bucket or strong bag, rather than being carried by the worker.
2. Tools should always be carefully handed from one employee to another – never tossed. Pointed tools should be passed either in their carrier or with the handles toward the receiver.
3. Workers carrying large tools or equipment on their shoulders should pay close attention to clearances when turning and maneuvering around the workplace.
4. Pointed tools such as chisels and screwdrivers should never be carried in a worker's pocket. Acceptable ways to carry them include in a toolbox, pointed down in a tool belt or pocket tool pouch, or in the hand with the tip always held away from the body.
5. Tools should always be put away when not in use. Leaving tools lying around on an elevated structure such as a scaffold poses a significant risk to workers below. This risk increases in areas with heavy vibration.
6. Wrong tool or poorly maintained tool should not be used for any job. Dull tools can make the work much harder, require more force and result in more injuries.
7. Defective tools should be taken out of service immediately and tagged or locked out to make sure no one else uses them until they are fixed.

4.2 Safety Challenges in Handling different Tools

Hand tools include a wide range of tools, from axes to wrenches. Eye injuries are very common from the use of hand tools, as a piece of wood or metal can fly off and lodge in the eye (Lockwood, 2021). The size of the tool is important: some women and men with relatively small hands have difficulty with large tools (Nagourney, 2008). A chisel with a mushroomed head might shatter on impact and send fragments flying. Cutting material at an awkward angle can result in a loss of balance and an injury. In addition, hand tools can produce sparks that can ignite explosions if the work is being done around flammable liquids or vapors. In such cases, spark-resistant tools, such as those made from brass or aluminum, are needed.

Power tools are more dangerous than hand tools, because of the increased power of the tool (Gibadi,, 2022) The biggest dangers from power tools are from accidental start-up and slipping or losing one's balance during use. The power source itself can cause injuries or death, for example, through electrocution with electrical tools or gasoline explosions from liquid-fuel tools (Elcosh, 2002). Most power tools have a guard, in proper working order and not overridden, to protect the moving parts while the tool is not in operation. A portable circular saw, for example, should have an upper guard covering the top half of the blade and an automatic-return retractable lower guard which covers the teeth while the saw is not operating and cover the lower half of the blade when the tool has finished working. Power tools often also have safety switches that shut off the tool as soon as a switch is released or have catches that must be engaged before the tool can operate (*Nagyszalanczy, 2001).*

One of the main hazards of ***electrical tools*** is the risk of electrocution (Tajuddin, 2019). A frayed wire or a tool that does not have a ground (that directs the electrical circuit to the ground in an emergency) can result in electricity running through the body and death by electrocution. This can be prevented by:

(a) using double-insulated tools (insulated wires in an insulated housing),
(b) using grounded tools and ground-fault circuit interrupters (which will detect a leak of electricity from a wire and automatically shut off the tool);
(c) by never using electrical tools in damp or wet locations; and
(d) by wearing insulated gloves and safety footwear.
(e) Power cords have to be protected from abuse and damage.

Other types of power tools include powered abrasive-wheel tools, like grinding, cutting or buffing wheels, which present the risk of flying fragments coming off the wheel. The wheel should be tested to make sure it is not cracked and will not fly apart during use. It should spin freely on its spindle. The user should never stand directly in front of the wheel during start-up, in case it breaks. Eye protection is essential when using these tools.

Pneumatic tools include chippers, drills, hammers and sanders that shoot fasteners at high speed and pressure into surfaces. These tools, otherwise known as air tools, are powered by compressed air and can be used in a variety of applications. While these powered tools are efficient and effective, there are several things to consider when it comes to the safe and proper handling of your pneumatic tools. If the object being fastened is thin, the fastener may go through it and strike someone at a distance. This results in the risk of shooting fasteners into the user or others (Butler, 2020). Pneumatic tools can also be noisy and cause hearing loss. Air hoses should be well connected before use to prevent them from disconnecting and whipping around and should be protected from abuse and damage. Compressed-air guns should never be pointed at anyone or against oneself. Eye, face and hearing protection are required when using these tools. Jack hammer users should also wear foot protection in case these heavy tools are dropped (Butler, 2020).

Gas-powered toolsare usually operated with gasoline. The most serious hazard associated with the use of fuel-powered tools comes from fuel vapors that can burn or explode and also give off dangerous exhaust fumes. The fuel explosion hazards occurs particularly during filling. They should be filled only after they have been shut down and allowed to cool off. Proper ventilation must be provided if they are being filled in a closed space. Using these tools in a closed space can also cause problems from carbon monoxide exposure (States and McQuaid, 2022).

Powder-actuated tools are like loaded guns and should be operated only by specially trained personnel. They should never be loaded until immediately before use and should never be left loaded and unattended. Firing requires two motions: bringing the tool into position and pulling the trigger. Powder-actuated tools, which should not be used in explosive atmospheres, require sufficient pressure against the surface before they can be fired. If the muzzle is not pressed against a surface with sufficient force, the firing pin is blocked and cannot reach the load to fire it. They should never be pointed at anyone and should be inspected before each use (Krueger, 2021). These tools should have a safety shield at the end of the muzzle to prevent the release of flying fragments during firing. Power tools present a considerable vibration, sprains and strains hazards to workers as in the chain-saw vibration. Tools where vibration has been dampened or reduced should be purchased.

Hydraulic power tools should use a fire-resistant fluid and be operated under safe pressures. A jack should have a safety mechanism to prevent it from being jacked up too high and should display its load limit prominently. Jacks have to be set up on a level surface, centered, bear against a level surface and apply force evenly to be used safely (Student Lesson, 2022).

Poorly designed tools can also contribute to fatigue from awkward postures or grips, which, in turn, can also lead to accidents. Many tools are not designed for use by left-handed workers or individuals with small hands. Use of gloves can make it harder to grip a tool properly and requires tighter gripping of power tools, which can result in excessive fatigue. Use of tools by craftsmen/technicians for repetitive jobs can lead to cumulative trauma disorders, like carpal tunnel syndrome or tendinitis. Safety Stage (2022) admonished technicians/technologists about using the right tool for the job and choosing tools with the best design features that feel most comfortable in the hand while working. This can assist in avoiding these problems, and make the work easier, safer and more efficient.

5. TOOL MAINTENANCE POLICY

Tools in the initial days always perform to their fullest capacity but as time goes with regular wear and tear, this becomes increasingly difficult. With proper and regular maintenance tool work capacity can be maintained at a more or less same level. Tools have always been the most crucial asset for workers. These are the tools that make your job possible. In return, you remain in debt to protect and maintain these tools, as maintenance and protection of the tools make them serve you for a longer time (Marsigroup, 2020). Maintenance at times requires replacement decisions whereby existing tool is replaced with a new one, which may enhance features capable of performing similar function. The need for replacement may arise because of normal use, obsolescence, early service failure, destruction, etc. Maintenance is defined as a process in which working condition of a tool/equipment is maintained at the optimum level as to give maximum output. Maintenance is done through repair, partial replacement and total replacement. Maintenance, therefore, is a very important workshop ethics. And any workshop should have a maintenance policy. Maintenance policy *ensures that equipment are always in ready and reliable condition (MSG, 2015)*. Following is the significance of the maintenance policy: it ensures that

1. Tools are always in ready and reliable condition.
2. Tools are always calibrated to provide good-quality services
3. There are no major breakdowns.

If an effective maintenance policy is not implemented, then the following results:

1. Full capacity utilization may not be achieved.
2. Increase in production cost as fixed labor cost cannot be reduced.
3. Increase in maintenance cost as more spare parts are required.
4. Reduction in product quality and increase in wastage.
5. Safety of workers and operators in jeopardy.

However, maintenance should be planned with the following key points:

1. Identify the tools/equipment for maintenance and technique for the maintenance.
2. Categorize maintenance into routine, priority and emergency.
3. Plan maintenance considering cost, time, space, etc.
4. Material planning for maintenance requirements.
5. Budget time and money requirements.

The need to schedule maintenance can be best described as follows:

1. To optimize usage of plant, machinery and tools.
2. To optimize usage of manpower in maintenance.
3. To ensure smooth production flow.

From above it is safe to posit that it is very critical and important for any workshop/laboratory to have a robust and effective maintenance and repair policy as part of its workshop ethics.

5.1 Inspect (and repair) Tools every time they are used

In a typical workshop, it is important to take time to inspect the tools every time they are to be used to ensure not only user safety while using them, but the longevity of the tools as well. In so doing, Simon (2018) suggested we look out for the following:

1. **Loose, cracked, or splintered handle** is prone to breaking during use, which can cause injury to you or others. If the handle is cracked or heavily splintered, you'll need to replace it.

2. **Mushroomed heads on tools like chisels and wedges** could shatter on impact when in use. Fortunately, this problem can be solved by keeping the tools sharpened. Plan to sharpen them every six months or so just as a habit or as soon as mushroomed heads are noticed.
3. **Corrosion and rust.** Depending on the level of corrosion or rust, the tool may be unsafe to use. Try removing the rust or just replacing the tool. Removing rust from tools is actually pretty easy if the damage isn't too great.
4. **Cracked housing on power tools.** If a power tool has anything more than a simple hairline crack on the housing, don't use it. Get it repaired by a professional before use.
5. **Power tools that don't start easily** should not be used. Take the time to clean and lubricate it and if that doesn't solve the problem, get it repaired by a professional.
6. **Frayed insulation or exposed wires are** obviously electrical hazards. While some electrical tape might take care of a small problem temporarily, it's best to have the tool repaired before using it.

5.2 Tool Safety

Good tools are an asset in any workshop and can be quite an investment, but they have to be taken good care of. Keeping the tools properly stored, cleaned, and maintained will save time and money. High point of tool safety is its storage which is a key workshop ethics (Newswise, 2011). Several tool storage options are safe and easy to use, allowing you to customize your tools and equipment to best fit your needs. No matter which tool storage option you choose, the important thing is providing a protected environment for the equipment (Frost, 2022).Tools must be stored properly working with the space available. They may be hung on pegboards, stored in boxes, bags, or chests, or may be kept in drawers or on shelves in the workshop. Improve your own efficiency by organizing your tools so that those used most frequently can be reached easily without digging through the entire contents of the box (Frost, 2022). Peg boards make a great storage system for tools as they let all the tools be seen at a glance and they can make use of wall space in a pretty efficient way. With insufficient wall space though, advantage can still be taken of peg boards by building a hinged system, a rolling peg board, or even a portable peg board storage system (Puisis, 2022) or use made of the flip board system. The portability of tool boxes makes for great tool storage. However, some people opt to store all their tools in tool boxes, but for most, the tool box is a way of carrying around the most-used tools while leaving the bulk safely stored on peg boards, shelves, or drawers.

Rust is public enemy number one when it comes to tools. To avoid rust when storing the tools CF-T (2022) made the following suggestions among others:

1. **Keep tools in a dry place** and avoid humid spaces.
2. **Hang the tools** so that they don't rest on the floor. Moisture can easily creep up from concrete floors.
3. **Store power tools in their original cases** unless you have a climate-controlled workshop. It's best to store power tools in the hard plastic cases they usually come with. Not only are they better-protected from humidity, they're just better-protected in general.

4. **Use silica gel packs or rust collector** that come in lots of packaging to keep moisture at bay. Toss them in drawers or toolboxes and they can help keep rust away. You can also buy rust inhibitors for the same purpose and even anti-rust liners for drawers and shelves.

As it is said, cleanliness is next to godliness, so it is with tools. Cleaning the tools after the day's work is essential for keeping them in good shape. Cleaning the tools doesn't have to be difficult at all if well prepared:

1. **Hand tools:** You can clean most hand tools by simply wiping them down with a rag. If they're dirty, don't be afraid to give them a good wash with soap and water and wipe with a clean rag. Wipe wooden handles with a rag dampened with a little linseed oil.
2. **Power tools**: Power tools are a little trickier to clean. First, make sure the tool is unplugged before cleaning it. Next, get all the dust off using an air compressor. Wipe down the surface of the tool and then lubricate any moving parts. Machine oil is a fine choice for this. However, check the manual that came with the tool to see if they have better recommendations.

Don't forget that the toolboxes, belts, and bags will need some care as well. Clean out the toolboxes every once in a while by emptying them and wiping them and condition the leather once in a while. For bags and belts not made of leather, a quick wash should do the trick.

6. PERSONAL SAFETY EQUIPMENT/PERSONAL PROTECTIVE EQUIPMENT (PSE/PPE)

Personal protective equipment (**PPE**) is protective clothing, helmets, goggles, or other garments or equipment designed to protect the wearer's body from injury or infection. The hazards addressed by protective equipment include physical, electrical, heat, chemicals, biohazards, and airborne particulate matter (Citation, 2012). Some of these are shown in Fig. 3.

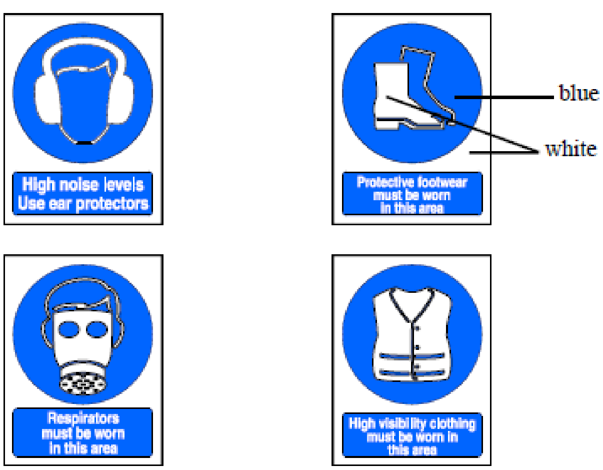

Fig. 3. Some personal protective equipment or Personal Safety Equipment (PPE/PSE) (Szawlowski, 2019).

Personal protective equipment/personal safety equipment (PPE/PSE) is defined as “all equipment (including clothing affording protection against the weather) which is intended to be worn or held by a person at work and which protects them against one or more risks to their health or safety” (Szawlowski, 2019). The tools/equipment in all workshops and laboratories and their use and misuse pose risks on the workers/employee, the environment and the tools/equipment. The risks may arise from biological, chemical, environmental and physical processes: radiation, UV light, X-rays; chemicals, biological agents; lifting, pushing, pulling; cold, wet, heat; noise; equipment hazards and general hazards. And there is the need for control measures by the use of gloves, footwear, respiratory protective equipment (RPE), eye/face masks/shields, hearing gear, body/head protectors and others. It is important that wear PPE/PSE all the time workers are exposed to risk.

6.1 General Body Protections

Different parts of the worker’s body should be protected when working in a laboratory/workshop: hands, feet, eyes, stomach, etc.

Gloves (Fig. 4)should be worn when handling: hazardous materials; toxic chemicals; corrosive materials; materials with sharp or rough edges; and very hot or very cold materials, as well as rough, scaly, or splintery objects. Special flameproof gloves are used for gas and electric-arc welding because of sparks and other hot flying objects. Electricians are usually required to wear insulating rubber gloves. Gloves are a kind of second skin that allows them to handle hazardous materials, chemicals, and tools without sacrificing the dexterity they need to perform their work skillfully (Fontaine, 2021).

Fig. 4. Hand protection glove (Szawlowski, 2019).

Safety shoes/boots are important in the workplace for: protection against falling objects, prevention of slips and falls, help posture and prevent muscle strain, protection against the elements, and help protect against electric shocks (Heath Brook, 2022). The ones with steel plate placed in the toe area prevent damage to the toes from falling objects. Other safety shoes are designed for use where danger from sparking could cause an explosion with rubber soles and non-metallic eyelets and nails.

Goggle is for proper eye protection. Eye protection is necessary because of hazards posed by infrared and ultraviolet radiation, or by flying objects such as sparks, globules of molten metal, or chipped concrete and wood. These hazards are ever-present during chipping, grinding, welding, cutting, soldering, and a variety of other operations. It is absolutely necessary to use eye protection devices, such as goggles, helmets, and face shields during eye-hazard operations. Some goggles have plastic lenses that resist shattering upon impact and others have appropriate filter lenses to limit harmful infrared and ultraviolet radiation from arcs or flames (Tajuddin, 2021).

The safety strap and body belt are called extra hands when one works aloft. The body belt, strapped around your waist, contains various pockets for small tools. The safety strap is a leather or neoprene-impregnated nylon belt with a tongue-type buckle at each end. While you are climbing you will have the safety strap hanging by both ends from the left ring (called a D-ring because of its shape) on the body belt. When you are at working position, you unsnap one end of the safety strap, pass it around the supporting structure so there is no danger of its slipping (at least 18 inches from the top of the part on which it is fastened), and hook it to the right D-ring on the body belt (Workplace, 2022).

6.2 Respiratory Protective Equipment (RPE) (Fig. 5)

Respiratory Protective Equipment (RPE) is a particular type of Personal Protective Equipment (PPE), used to protect the individual wearer against the inhalation of hazardous substances in the workplace air (HSA, 2022).

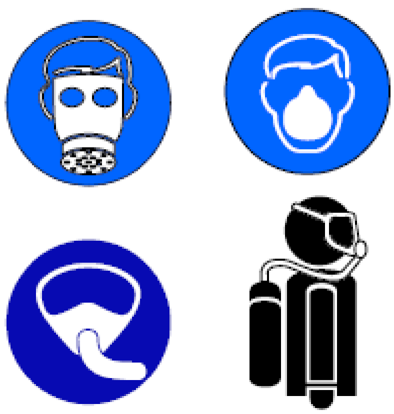

Fig.5. Some respiratory protective equipment (RPE) (Szawlowski, 2019).

Respiratory protection may be required against poisonous gases, vapors and fumes, dusts and aerosols, and biological agents, etc. RPE, which provides absolute protection against a respiratory hazard, must be selected carefully to ensure it gives adequate, if not absolute, protection depending on the toxicity of the agent, the size of the particle, the amount of movement involved in the task and working conditions, the worker’s face shape, presence of beard, glasses etc. and the Workplace Exposure Limit (WEL) of the substance and contaminant levels (HSA, 2022).

RPE consists of two (2) major categories: respirators (air purifying) which filter contaminated air (simple filtering and powered) and breathing apparatus or equipment that provides clean air from independent external or outside source (air supplied) (simple compressed-air apparatus, fresh air hose equipment and breathing apparatus) (HSA, 2022). There are several types of RPE as shown below (Putter, 2021):

Paper filters which cover chin, nose and mouth only protects against dust particles and not against vapors and gases.

Disposable half mask containing both gas and dust particle filtering elements protects against dust particles and certain types and quantities of gases and vapors.

Half mask covering chin, mouth and nose made of silicon or rubber with replaceable parts to protect against dust and gas hazards.

Full mask covering all the face made of silicon or rubber with replaceable parts protects against dust and gas hazards.

Positive full face hood/helmet protects against dust particles and certain gas and vapor hazards.

Power assisted full face mask respirator protects against both particulate and gas/vapor hazards.

6.2.1 Use and maintenance of RPE

All masks must be face fitted by appropriately trained personnel, while the wearer must be trained on how to use and maintain them. Maintenance is a requirement for all RPE, except for disposable (single use) RPE, and should be carried out by properly trained personnel.The masks must be inspected thoroughly before use and on regular basis of not more than once a month. Selected RPE has to offer an adequate protection to the hazard and to reduce exposure to the level required to preserve the wearer's health. Furthermore, the RPE has to be suitable for the wearer, task and environment, in such a way that the wearer can work freely and without additional risks due to the use of RPE (HSE, 2013). Therefore, RPE must be adequate and suitable. Not wearing the correct RPE can result in ill health, and in some environments, such as confined spaces, it can be lethal to workers if there is toxic gases or oxygen depletion (Putter, 2021).

6.3 Eyes and Face Protection (Fig. 6)

If you are exposed to dust, acids, molten metal's, grinding wheels, hazardous optical radiation – you need to take the proper precautions and protect your eyes. If you don't, it's possible to lose the precious gift of sight.

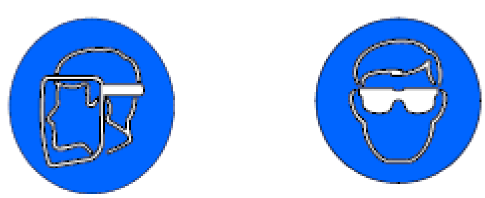

Fig. 6. Some eye and face protection (Szawlowski, 2019).

According to Owczarek (2022), each type of individual protection PPE is made to protect our eyes from contact with something that we call a harmful or dangerous factor. Examples of these factors are: Impact (e.g. fragments of solid bodies), Optical radiation (e.g. radiation related to welding processes, sunglare, laser radiation, , ionizing radiation, UV), Dusts and gases (e.g. coal dust welding fumes or aerosols of harmful chemical substances), Droplets and splashes of fluids (e.g. splatters appearing while pouring fluids), Melted metals and hot solid bodies (e.g. chips of melted metals appearing in metallurgical processes), Electric arc (e.g. occurring while conducting high-tension works, sparks, etc.). To protect eyes against these harmful or dangerous factors, they come as Spectacles; Protective goggles; Face shields; Welder's face shields (this category of eye protection includes hand screens, face screens, goggles and hoods) (Owczarek, 2022).

6.4 Hearing Protection (Fig. 7)

Noise is a serious problem in some industrial workshops. Hearing protectors are required to prevent noise-induced hearing loss. Hearing protection devices reduce the noise energy reaching and causing damage to the inner ear.Occupational hearing loss is one of the most pervasive problems in today's occupational environment, affecting workers in manufacturing, construction, transportation, agriculture, and the military (Franks *et al*., 1996).

Fig. 7. Hearing protection (Szawlowski, 2019).

Risk from noise which can cause temporary or permanent deafness may arise if there is constant noise above 80db for an 8 hour work period; impact noise; and explosive noise (EHS, 2022). Ear protection comes in the form of:

Ear plugs - which fit inside the ear canal, may not be suitable for people with a history of ear problems.

Canal caps - soft rubber caps attached to a headband which presses them into the openings of the ear canal.

Ear muffs – hard plastic cups with sound absorbent filling which fit over the ears and are sealed to the head by cushions. They are pressed to the head by means of a head band or some special fittings attached to some types of safety helmet.

6.5 Foot Protection (Fig. 8)

Foot protection is any piece of personal protective equipment (PPE) protecting one's foot from any injury while at work or during movement. The foot is a vital part of our body and since we are on our feet constantly from day to day, they are more susceptible to injury. If a foot is injured, our movement may be temporarily or permanently restricted (Safeopedia. 2018)

Fig. 8. Foot protection (Szawlowski, 2019).

Where there the risk of crush or impact injuries; chemical or molten metal burns; contamination with harmful substances; penetration with sharp objects e.g. glass; or slipping, an appropriate safety footwear should be put on. On slippery floors workers should put on anti-slip footwear and steel toe-capped boots if there is likelihood of crush or impact injuries. According to EHS (2022a), foot and leg protection choices include the following:

- Safety-toed shoes or boots protect against falling, crushing or rolling hazards. Safety-toed footwear must meet the minimum compression and impact performance standards in ANSI Z41-1999 or provide equivalent protection.
- Some safety shoes may be designed to be electrically conductive to prevent the buildup of static electricity in areas with the potential for explosive atmospheres or nonconductive to protect workers from workplace electrical hazards.
- Metatarsal guards protect the instep area from impact and compression. Made of aluminum, steel, fiber or plastic, these guards may be strapped to the outside of regular work shoes.
- Toe guards fit over the toes of regular shoes to protect the toes from impact and compression hazards. They may be made of steel, aluminum, or plastic.
- Rubber overshoes are used for concrete work and areas where flooding is a concern
- Shoes with slip-resistant soles are required for certain departments and should be used in areas where slips and falls on wet floors are most likely.
- Studded treads and overshoes should be used when employees must work on ice or snow-covered walking surfaces.
- Leggings protect the lower legs and feet from heat hazards such as molten metal or welding sparks. Safety snaps allow leggings to be removed quickly.

6.6 Head Protection (Fig. 9)

Head protection is required when working in an area with the potential of an object falling and hitting the head or when there is a significant electrical shock exposure to the head. Head protection is an item of personal protective equipment (PPE), which is generally designed to protect the scalp area and sometimes the jaw as well and protects these areas from impact trauma and burns (Safeopedia, 2018a).

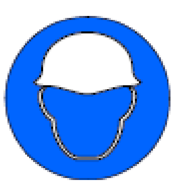

Fig. 9. Head protection (Szawlowski, 2019).

Head protection includes: industrial safety helmets; scalp protectors (bump caps); and caps, hairnets etc. Head protection should: be of an appropriate shell size for the wearer; and have an easily adjustable headband, nape and chin strap.

6.7 Body protection clothing (Fig. 10)

Protective clothing is any clothing specifically designed, treated or fabricated to protect personnel from hazards that are caused by extreme environmental conditions, or a dangerous work environment (Safeopedia, 2018b).

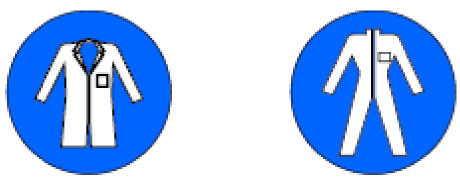

Fig. 10. Body protection (Szawlowski, 2019).

Protective clothing including standard lab coats, over coats or aprons should be worn to protect against: hazardous substances; machinery parts; and extreme conditions. Loose clothing must not be worn near machinery due to the risk of it become trapped by moving parts. Body protection should be washed regularly. Barrier creams may also be used as a form of body protection. These include: sunscreens to protect parts of your body from UV radiation that are not easily protected by clothes and thus protect against subsequent skin cancer when working outdoors or on field trips; hand creams to be used when wearing gloves for long periods of time which reduce the chances of developing contact dermatitis; where workers have to frequently wash their hands.

6. 8 Guidelines for human and machine safety in workshop

Safety, according to Bello (2012), is a state of being at little or no risk of injury resulting from a harmful external impact, inhalation, or contact. Safety in any work environment hinges on prevention and mitigation of harm which is approached using three (3) steps of ***Recognition:*** Identify hazards to which a person at the workplace is likely to be exposed**; *Evaluation***: Assess the risk of injury or harm to a person resulting from each hazard; and ***Control:*** Consider the means by which the risk may be reduced. In all these, it is the human person that mitigates or prevents harm and any human error causes accident. Therefore, the technologist or technician or craftsman in the workshop has the responsibility to eliminate or minimize errors to the barest minimum for safety in the workplace.

Injuries occur when workers are:

a) not paying close attention (or are indifference) to work, or

b) when the operator lost concentration or forgot something and was not paying close attention,

c) when he/she took a risk, ignored a warning or

d) when he/she failed to follow safety rules.

Workshop safety rules include the following (StopLearn, 2022):

1. Wear industrial protective clothing coat or apron.
2. Wear protective pair of shoes with strong toe caps.
3. Do not carry sharp tools in your pockets. Put them on a tool rack.

4. Keep tools in the locker after use.
5. Keep your sharp tools in a safe place.
6. Do not use chisels or file without handles.
7. Give out chisel and other sharp edged tools by the handle.
8. Keep your hand behind the cutting edge of chisel when using it for cutting.
9. Select the right tools for the job.
10. Wear goggles or eye shield while griddling your tools.
11. Do not fiddle with the ‘on’ and ‘off’ switches of the machine and appliance.
12. Do not run around in the workshop.
13. Do not make alarming noise in the workshop.
14. Do not operate a machine, unless you have been taught its working operation, and obtained permission before use.
15. Give the machine your undivided attention during operation.
16. Start and wait until a machine gathers its operating speed before use.
17. Stop the machine after operation.
18. Do not overload a machine.
19. Do not allow the workshop floor to become slippery.
20. Report any injury no matter how small.
21. Ask for the first aid treatment when necessary.

Employers have a duty to minimize the risk of injury at their workplace by ensuring a safe work environment through inductions, training and re-training.

7. CONCLUSION

This reviewed paper has tried to highlight the importance of workshop ethics: selection and handling of laboratory/workshop tools and equipment. It has looked at the purpose and function of safety; selection of tools/equipment; tool work habit, work ethics and tool management policy; the importance of wearing and caring of PPE; the use and maintenance of RPE. All for the purpose of running a safe workshop/laboratory.

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DESIGN AND FABRICATION OF A YAM MOUND MAKING IMPLEMENT

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ABSTRACT
Yam (Dioscorea species) is among the oldest recorded food crops and rank second after cassava in the study of carbohydrates in West Africa. It also forms an important food source in other tropical countries including East Asia, Africa, South America, South East Asia (including India). Nigeria is the largest producer of the yam, producing about 38.92 million metric tons annually. A tractor operated yam mound making implement capable of producing 2,560 mounds per day was design and fabricated The field test carried out showed that the average inter and intra row spacings were 1.22 and 1.12 m respectively, while the average diameter and height of mounds produced were 1.21 and 0.50 m. The average time taken to produce a mound was 297 sec (4.95 min). Comparing the mechanical yam mound making implement with manual yam making, the work rates for producing 2,560 and 160 mounds were 12.72 h/ha and 72h/ha respectively. The yam mound making implement is expected to reduce drudgery considerably and increase the country's earning from yam exportations.

KEYWORDS: Yam, mounds, machine design, mound maker

1. INTRODUCTION

Yam (*Dioscorea species*) is among the oldest recorded food crops and rank second after cassava in the study of carbohydrates in West Africa (Agwu and Alu, 2005). It also forms an important food source in other tropical countries including East Asia Africa, South America, South East, Asia including India (Ayanwuyi et al., 2011). Nigeria is the largest producer of the crop, producing about 38.92 million metric tonnes annually (FAOSTAT 2008). Six species, namely white yam (*Dioscorearotundata*), yellow yam (*Dioscoreacayenensis*), water yam (*Discoreaalata*), Trifoliate or three- leaved yam (*Dioscoreadumentorum*). Arial yam (*Dioscoreabulbifera*) and Chinese yam (*Dioscoreaesculenta*) can be considered the principal edible yams of the tropic (Ironkwe, 2010). Yam tubers are eaten boiled, roasted, fried or pounded and could be chipped, dried and processed into yam flour. Yam represents about 20% of the daily calorie intake of Nigerians living in the forest and savannah region (Agwu and Alu, 2005). Yam constitutes a major staple food for the majority of inhabitants of Nigeria. Yam has potential for livestock feed and industrial starch manufacture. Traditionally, yam is a prestigous crop that is view and received with high respect, prominently during special gatherings such as new yam festivals in rural communities of eastern, central and some parts of south west of Nigeria. There has been a general decline in yam production in Nigeria over years (Ayanwuyi *et al.,* 2011). International Institute of tropical Agricultural (IITA, 2002) reported that both area under yam cultivation and total yam output were declining. However, yam production in Nigeria is faced with a number of constraints paramount among these constraints are pest and disease attack, procurement of the required seed yam for more yam production, its reoccurring scarcity and high cost during planting season (Ayanwuyi *et al.,* 2011).

Land preparation for yam cultivation is one of the major constraints to its production, and this restricts farm expansion and productivity of farmers as well as their income. Mounds are usually made with hoes and high cost to cover larger areas of land. However, tractor-mounted implements have been devised to fast-track the mound-making rate and cut off the laborious land preparation. The Department of Farm Power and Machinery at the National Centre for Agricultural Mechanization (NCAM), Ilorin, Kwara State, has designed and developed a mound-making implement to address the issue of making mounds during yam production.

The yam mound implement is a tractor-mounted implement designed and fabricated to make mounds for yam cultivation. The overall objective of this research is to reduce the drudgery laden with yam cultivation by reducing the effort and time taken to create heaps on a well ploughed land and to make harvesting easier as the heaps are created and spaced uniformly by the implement.

2. MATERIALS AND METHODS

The machine consists mainly of the following component parts: frame, propeller shaft, spiral gear pinion, standard, disc blade, support stand, top and lower link. The machine design was carried out using principles of engineering design with due consideration to cost, ease of operation, serviceability and durability.

2.1 Description of the Implement

The yam mound making implement was fabricated with locally sourced materials. The orthographic projection and exploded view of the implement are as shown in Figures 1 and 2, respectively. A mild steel square pipe of 5 mm was used to fabricate the frame of yam mound making machine upon which other components are attached and the pipe has the ability to withstand bending or twisting forces. The three-point linkages were constructed using a 16 mm thick mild steel flat bar to form a triangular shape, attached to the main frame which enable the mounting of the yam mound making machine on the three-point linkages of a tractor for ease of operation on the field.

The propeller shaft is used in transmitting power from the tractor PTO shaft to the disc blades for making of mounds. Two joints were constructed at both ends of the propeller shaft for PTO shaft and pinion head respectively. Spiral gear of 420 mm diameter was used to convert linear motion into vertical motion driven by the pinion head attached to the propeller shaft. The Standard **i**s the component that connects the disc bearing to the main frame and is fabricated with mild steel flat bar of 50 mm thickness. The standard is either a movable type which can then be shifted or a type with a pivoting bearing bracket at its lower end where the disc bearing is attached. Disc blades are at an angle to the direction of travel so both radial and thrust forces are present. Radial forces push against an axle at right angle while thrust forces push along the axis. That is why taper roller bearings are used. Disc type blades are mounted for cutting of soil. Blades diameter determine mounds capacity. Concavity affects disc angle and soil turning. Shallow concavity depends on diameter of discs. Depth of cut depends on diameter of discs. About $1/3^{rd}$ of blade diameter is the limit for depth. Width of cut depends on diameter of blade. Width of cut is normally 0.4 times of diameter of disc blade. As shown in Figure 3, the angle at which the plane of cutting edge of disc is inclined to direction of travel is called disc angle. It varies from 42 to 45 degree.

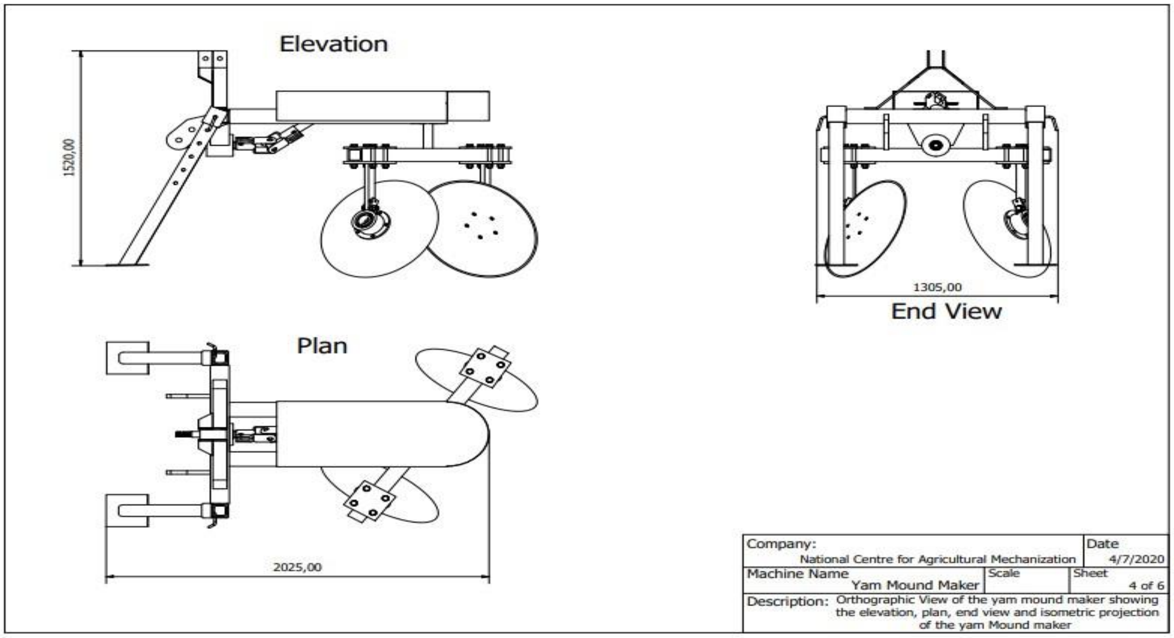
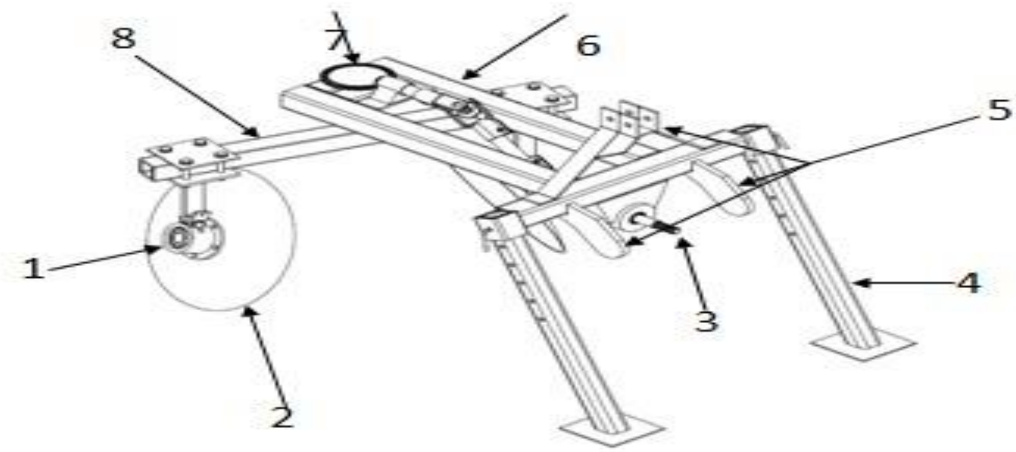


Fig. 1.Orthogrphic projection of the implement



Key	Part Name
1	Bearing Hub
2	Disc Plough
3	PTO Shaft
4	Jack Stand
5	Tri-Point Linkage
6	Main Frame
7	Bevel Gear

Fig. 2. Exploded views of the implement

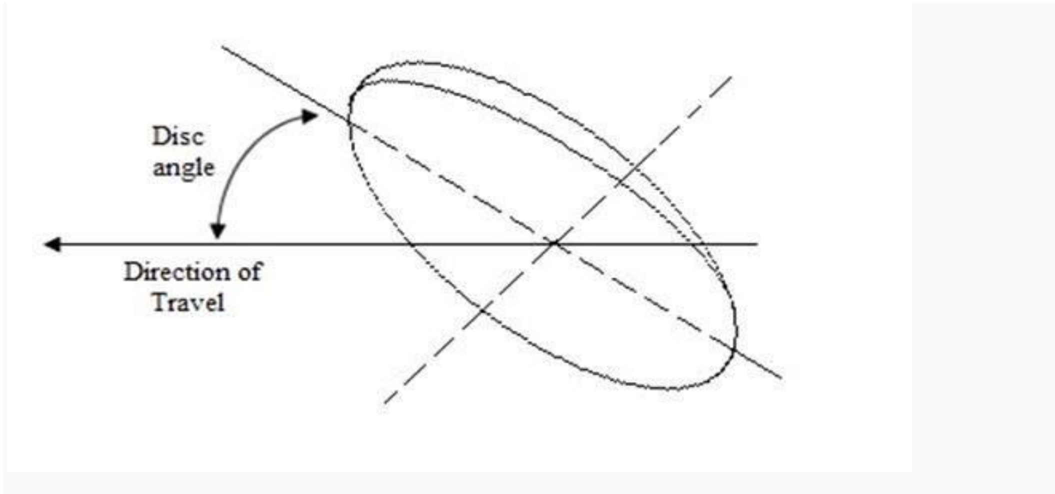


Fig. 3. Disc cutting angle

2.2 Mathematical Analysis

2.2.1 Propeller shaft

The shaft is cylindrical in shape made of mild steel material, shaft is subjected to Torsional, bending, axial load and combination of the above three loads (Khurmi and Gupta, 2005)

$$\frac{T}{J} = \frac{\tau}{R} \quad 1$$

where, $T = Twisting\ moment\ (or\ torque) acting\ upon\ the\ shaft$ (Nm)
$J = Polar\ moment\ of\ inertial\ of\ the\ shaft\ about\ the\ axis\ of\ rotation$ (m^4)
$\tau = Torsional\ shear\ stress$ (Pa)
$R = distance\ from\ neutral\ axis\ to\ the\ outer\ most\ fibre$ (m)

$$\mathrm{T} = \frac{\pi}{16}\tau\left[\frac{D^4 - d^4}{D}\right] Torsional\ load\ for\ hollow\ shaft \quad 2$$

$$J = \frac{\pi}{32}(D^4 - d^4) \text{Polar moment of inertial for hollow shaft} \quad 3$$

where, D^4 = Outside diameter(m)
d^4 = inside diameter (m)

The power transmitted by the shaft is given as:

$$P = \frac{F \times 2\pi RN}{60}\ watts \quad 4$$

$$P = \frac{2\pi NT}{60 \times 1000} \quad 5$$

where, P = Power transmitted by shaft (watt), N= Number of revolutions per minute (sec), T= Torque applied (Nm)

A column factor (α) is considered when the shaft is long and subjected to compressive load is given by (Khurmi and Gupta, 2005) as:

$$\sigma_c = \frac{\alpha \times 4F}{\pi (d_o)^2 \, (1-K^2)} \quad For\ hollow\ shaft \qquad 6$$

The value of column factor (α) for compressive load may be obtained from the following relation

$$\alpha = \frac{1}{1-0.0044\left(\frac{L}{K}\right)} \qquad \text{Where } \left(\frac{L}{K}\right) < 115 \qquad 7$$

$$\alpha = \frac{\sigma_y \left(\frac{L}{K}\right)^2}{C\pi^2 E} \qquad \text{Where } \left(\frac{L}{K}\right) > 115 \qquad 8$$

where, L = Length of the shaft between bearing (m), K = least radius of gyration, σ_y = Compressive yield point stress of the shaft material and coefficient in Euler's formular depending upon the end

The equation for equivalent twisting moment (T_e) and equivalent bending moment (M_e) is given by (Khurmi and Gupta, 2005) as:

$$T_e = \sqrt{\left[K_m \times M + \frac{\alpha F d_o (1-K^2)}{8}\right] + (K_\tau \times T)^2} \qquad 9$$

$$M_e = \left[K_m \times M + \frac{\alpha F d_o (1-K^2)}{8} + \sqrt{\left\{K_M \times M + \frac{\alpha F d_o (1-K^2)}{8}\right\} + (K_\tau \times T)^2}\right] \qquad 10$$

where, T_e = Equivalent twisting moment (Nm), M_e = Equivalent bending moment (Nm), F = Maximum tensile stress (Mpa), T = Actual torque (Nm), M = actual bending moment (Nm), d = diameter of the shaft (m), K_m = combined shock and fatigue factor for bending, K_t = combined shock and fatigue factor for torsion, α = column factor and σ = principal stress

2.2.2 Crown wheel and pinion

Gears are defined as toothed members transmitting rotary motion from one shaft to another. There exist a variety of gear types, each of which serves arrange of functions. Helical gears have teeth inclined to the axis of rotation and are used to transmit motion between parallel or nonparallel shafts. Pairs of helical gears transmit power, so that the both shafts are subjected to a thrust load. Spiral teeth engage gradually (starting at one side), a feature enabling them to operate much more smoothly and quietly. The inclination of the teeth causes an overlapping action. Therefore, more than one tooth is in contact with others at all times (Ashby, 2005). Because of this continuous engagement, the load is transmitted more smoothly from the driving to the driven gear than with straight bevel gears. Spiral bevel gears as shown in Figure 4 have more load-carrying capacity together with more teeth in contact than the straight one the drive pinion in yam mound making machine are spiral bevel gears. Hypoid gears are quite similar to spiral bevel gears except that the shafts are off set and nonintersecting. This feature provides many design advantages. In operation, hypoid gears run even more smoothly and quietly than spiral bevel gears and are somewhat stronger. In addition, hypoid gears can carry more power, provided the speed is not too high (Ashby, 2005).

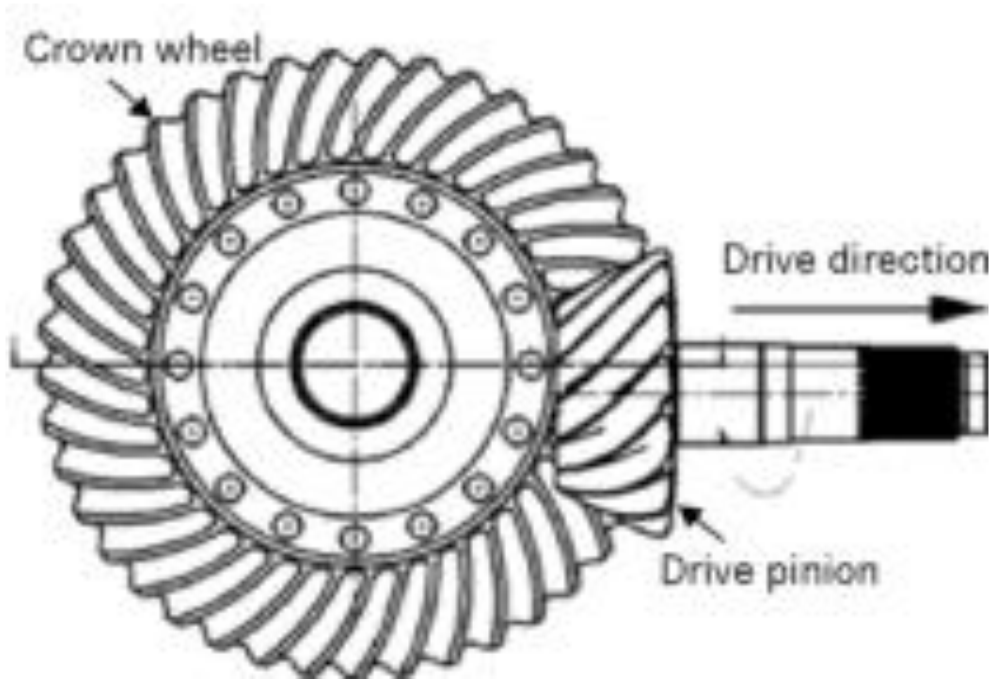


Fig. 4. Spiral toothed bevel gears with hypoid intersection between drive pinion and crown wheel axes

2.2.3 Shaft and bearing

The term shaft refers to a member of a round cross section that rotates and transmits power while the word bearing, applied to a machine or structure, refers to contacting surfaces through which a load is transmitted. Together shaft and bearing provide the axes of rotation of elements gears. The shaft transmits the stresses to the supports in which reactions are created and it transmits the torque to or starting from gears. Shafts should be supported by bearings which produce radial and axial bearing reaction (Klingelnberg, 2008).

The drive pinion consists of the spiral bevel gear and the shaft. The latter is subjected to various combinations of axial, bending, and torsional loads which are fluctuating. The drive pinion as a rotating component, transmitting power, is subjected to a constant torque (producing a mean torsional stress) together with a completely reversal bending load (producing an alternating bending stress). Furthermore, the applied bearings for the drive pinion shaft are tapered roller bearings. The bearing forces on the drive pinion can be calculated from the tooth forces and additionally acting external forces. The radial force to the bearing in this case contains components from the tangential, the axial and radial tooth force and the additional external forces. The axial force to the bearings is the axial tooth force plus the external forces (Klingelnberg, 2008).

Teeth contacts in bevel gears generate stresses that are tangential, radial and axial in relation to wheels. The axial stresses are parallel to the shaft and they create stresses due to bending as shown in Figure 5. The resolution of resultant tooth force F is into tangential, radial and axial components, designated as Ft (tangential forces), Fr (radial forces) and Fa (axial forces) and is shown in Figure 5, these forces are acting at the gear tooth, when contacting the crown wheel. Two taper roller bearings are located near the gear part (Klingelnberg, 2008).

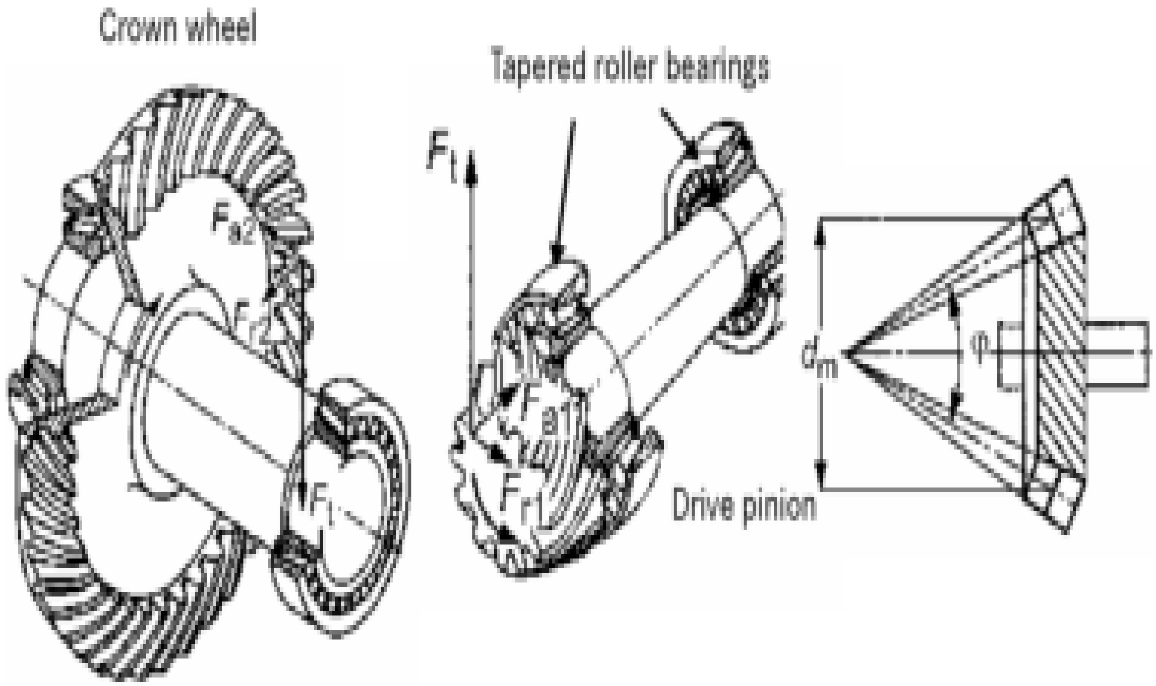


Fig. 5. Forces acting on spiral-toothed bevel gears

These factors can be calculated from the tangential, the axial and radial forces for the right-hand spiral with clockwise motion as:

$$F_a = \frac{F_t}{\cos\beta_m}(\tan\alpha_n \sin\varphi + \sin\beta_m \cos\varphi) \qquad 11$$

$$F_r = \frac{F_t}{\cos\beta_m}(\tan\alpha_n \cos\varphi - \sin\beta_m \sin\varphi) \qquad 12$$

where, ϕ = is the reference cone angle of examined gearwheel and

αn = is the meshing angle normal

βm = represents the spiral angle at the reference cone in tooth center.

The gear ratio is also defined as the ratio of the number of teeth of the wheel to the number of teeth of the pinion (Klingelnberg, 2008).

$$U = \frac{Number\ of\ teeth\ of\ the\ crown\ wheel}{number\ of\ teeth\ of\ the\ drive\ pinion} = \frac{Z_1}{Z_2} \qquad 13$$

2.2.4 Calculating the Radius of Curvature of Discs

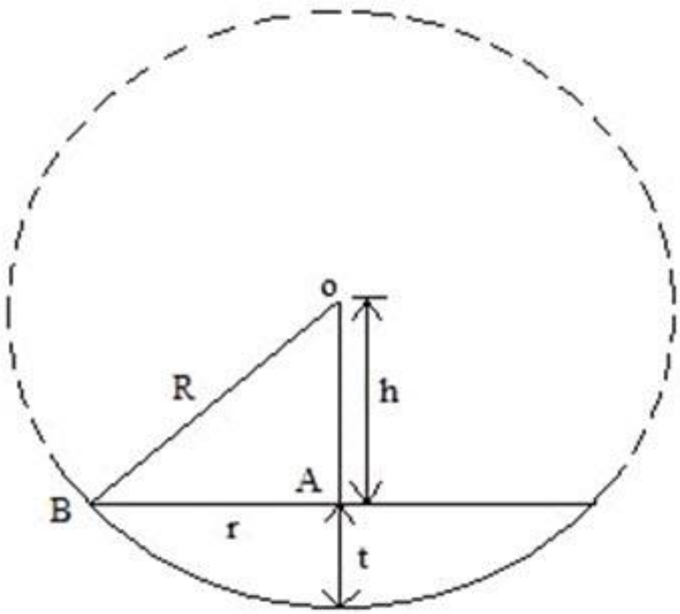


Fig. 6. Radius of Curvature of Discs

R − *Radius of Curvature*

r − *Radius of disc*

t − *Depth or concavity*

OAB

$$R^2 = h^2 + r^4$$

Also, $h = R - t$

$$h^2 = (R - t)^2$$

$$h^2 = R^2 - 2Rt + t^2$$

$$R^2 = R^2 - 2Rt + t^2 + r^2$$

$$2Rt = t^2 + r^2$$

$$R = \frac{t^2}{2t} + \frac{r^2}{2t}$$

$$R = \frac{t}{2} + \frac{\left(\frac{D}{2}\right)^2}{2t}$$

$$R = \frac{t}{2} + \frac{D^2}{8t} \qquad 14$$

2.3 Performance Evaluation of the Yam Mound making Machine

2.3.1 Field evaluation procedures

The performance evaluation of the yam mound making machine was carried out in the department of Farm power machinery at National Centre for Agricultural Mechanization (NCAM) Ilorin Kwara State. One hectare of land was plough for the evaluation of the yam mound making machine. Demarcation of the prepared land into three portion was done using survey tape and ranging poles, digital stop watches were used for time taken to make a mound and time interval between a mound to the other, the diameter, height, inter and intra row spacing were measured using steel rule and measuring tapes respectively. The parameters were taken randomly in the three fields.

The inter, intra row spacing, height and diameter of the mounds were determine using the steel rule, survey tape and ranging poles, a ranging pole is stake vertically beside a mound then steel rule is placed horizontally at the tip of the mound intercepting with the ranging pole for the height determination, two ranging poles are stake vertically at the base of a mound opposite to each other while measuring tape is use to determine the distance apart of the two ranging poles which give the diameter of the mounds, determining inter and intra row spacing is carried out by measuring the distances between mound to mound and row to row respectively.

2.3.2 Performance parameters

Field performance parameters measured included time, field capacity, field efficiency, inter and intra row spacing and height of mounds.

2.3.2.1 Theoretical Field Capacity

Theoretical field capacity of yam mound is the rate of field coverage that would be obtained if the yam mound maker performing its function100% of the time at the rated forward speed and cover 100% of its rated width. It is expressed as hectare per hour and determined (Aniekwe and Mbah 2014).

$$TFC = \frac{W \times S}{100} \qquad 15$$

where,

TFC= Theoretical Field capacity, (ha/h)
W =Eeffective width of implement (m)
S =Speed of operation, (km/h)

2.3.2.2 Field efficiency

Field efficiency is the ratio of effective field capacity to theoretical field capacity. The formula below was used to determined field efficiency (Aniekwe and Mbah 2014).

$$FE(\%) = \frac{EFC}{TFC} \times 100 \qquad 16$$

where,

$FE = Field\ Effieciency$
$EFC = Effective\ field\ capacity\ (ha/h.)$
$TFC = Theoritical\ field\ capacity(ha/h.)$

2.3.2.3 Effective field capacity

Effective field capacity of the yam mound was actual rate of work covered by the yam mound machine based upon the total field time and a function of rated width of the machine actually utilized and expressed as hectare per hour (Aniekwe and Mbah 2014).

$$\mathrm{EFC} = \frac{\mathrm{A}}{\mathrm{T}} \qquad 17$$

where,

$\text{EFC} = \text{Effective field capacity} \left({}^{\text{ha}}/_{\text{h}}\right)$

$\text{A} = \text{Actual area covered, ha}$

$\text{T} = \text{Time required to cover the area, h}$

3. RESULTS AND DISCUSSION

The results are presented in Tables 1 and 2. Table 1 shows yam mounds made mechanically with yam mound making machine while Table 2 shows the manually produced mounds by manpower with a single labourer. Table 3 shows the compared parameter analysis of mechanically and manually mounds made respectively.

The results obtained from Table 1 indicate mechanical mounding. The average inter and intra row, diameter and height of mounds were taken randomly from the field as carried out judging the machine. The average result in table1 shows that inter and intra row spacing is 1.62 and 1.45 m while the average diameter and height of 1.35 and 0.42 m at the average time of 7.40 sec. respectively

Table 2 present the results for manually mounding. The average inter and intra row is 1.22 and 1.12 m while the diameter and height of mounds 1.21 and 0.50 m at the average time of 297 sec (4.95 min)

Table 3 shows the analysis and comparison of the field parameters of mechanical and manual yam mound making which indicate that 2560 mounds were made within the work rate of 12.72 h/ha mechanically while 160 mound were made within the work rate of 72 h/ha manually.

The inter, intra row spacing, height and diameter of the mounds were determine using the steel rule, survey tape and ranging poles, a ranging pole is stake vertically beside a mound then steel rule is placed horizontally at the tip of the mound intercepting with the ranging pole for the height determination, two ranging poles are stake vertically at the base of a mound opposite to each other while measuring tape is use to determine the distance apart of the two ranging poles which give the diameter of the mounds, determining inter and intra row spacing is carried out by measuring the distances between mound to mound and row to row respectively.

Table 1. Mounds made with yam mound implement

S/N	Time taken to make a mound (sec)	Time interval between mounds (sec)	Inter–row spacing (m)	Intra-row spacing (m)	Diameter of mounds (m)	Height of mounds (m)
1	12	3	1.53	1.47	1.35	0.33
2	7	3	1.71	1.32	1.13	0.38
3	5	2	1.53	1.56	1.12	0.44
4	3	2	1.38	1.53	1.25	0.38
5	7	2	1.75	1.45	1.41	0.37
6	8	3	1.73	1.40	1.35	0.45
7	10	2	1.48	1.34	1.30	0.38
8	5	2	1.60	1.30	1.44	0.48
9	10	3	1.72	1.45	1.40	0.45
10	5	2	1.77	1.36	1.37	0.43
11	9	3	1.72	1.34	1.42	0.41
12	7	3	2.00	1.59	1.42	0.42
13	5	2	1.90	1.39	1.42	0.46
14	8	4	1.58	1.34	1.44	0.45
15	7	3	1.46	1.43	1.38	0.46
16	5	3	1.52	1.41	1.37	0.43
17	7	4	1.50	1.43	1.36	0.44
18	11	3	1.59	1.40	1.38	0.44
19	12	4	1.58	1.62	1.42	0.45
20	5	4	1.42	1.63	1.36	0.45
AVG	**7.40**	**2.90**	**1.62**	**1.45**	**1.35**	**0.42**

Table 2. Manual making of mounds with manpower

S/N	Time taken to make a mound (sec)(min)	Time interval between mounds (sec)	Inter–row spacing (m)	Intra-row spacing (m)	Diameter of mounds (m)	Height of mounds (m)
1	360(6)	3	1.30	0.98	0.88	0.48
2	300(5)	4	1.31	0.92	1.00	0.50
3	300(5)	2	0.89	0.87	0.99	0.53
4	180(3)	4	1.38	0.90	1.25	0.56
5	420(7)	2	0.90	1.15	1.40	0.46
6	480(8)	5	1.25	1.10	1.34	0.47
7	240(4)	5	1.48	1.99	1.35	0.55
8	300(5)	6	1.31	1.32	0.99	0.48
9	300(5)	3	1.12	1.16	1.39	0.50
10	300(5)	10	0.95	0.98	0.90	0.55
11	240(4)	6	1.40	1.20	1.40	0.47
12	180(3)	3	0.98	1.12	1.20	0.48
13	300(5)	5	0.90	1.14	1.32	0.52
14	240(4)	4	1.20	0.98	1.32	0.59
15	420(7)	12	1.16	0.99	1.34	0.54
16	300(5)	3	0.95	1.15	1.33	0.39
17	420(7)	4	1.40	1.19	1.10	0.54
18	240(4)	3	1.32	1.22	0.99	0.53
19	120(2)	4	0.89	1.00	1.35	0.49
20	300(5)	2	1.31	0.99	1.28	0.36
AVG	**297(4.95)**	**4.50**	**1.22**	**1.12**	**1.21**	**0.50**

Table 3. Analysis of mechanical and manual mounds

S/N	Parameters	Mechanical yam mound produced	Manual yam mounds produced
1	Number of mounds per day	2560	160
2	Number of mounds per hour	320	20
3	Number of mounds per hectare	4070	1440
4	Effective field capacity (ha/h)	0.0786	0.0138
5	Work rate (h/ha)	12.72	72
6	Height of mounds (m)	0.42	0.50
7	Diameter of mounds (m)	1.35	1.21
8	Inter row spacing (m)	1.62	1.22
9	Intra row spacing	1.45	1.12
10	Fuel consumption		
	(l/ha)	28.57	-
	(l/h)	1.99	-
11	Labour requirement	1	1
12	Tractor capacity (Hp)	95	-
13	Tractor PTO speed (rpm)	500	-

4. CONCLUSION

A yam mound making implement was designed, fabrication and evaluated, capable of making 2560 mounds per day at work rate of 12.72 h/ha. The yam mound making implement is recommended proper performance and evaluation with different soil types and content in different geo-political zones of the country where yam is cultivated for further improvement and adaptation of the implement

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EFFECT OF LAND FRAGMENTATION ON INPUT USE, YIELD AND PRODUCTION EFFICIENCY OF ARABLE CROP FARMERS IN IHIALA LOCAL GOVERNMENT AREA OF ANAMBRA STATE, NIGERIA

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ABSTRACT
This study analyzed impact of land fragmentation on the input use, yield and production efficiency of arable crop farmers in Ihiala local Government area, Anambra State, Nigeria. A multi-stage sampling procedure was used to select 90 respondents for the study. Data collected using well-structured questionnaire were analyzed using means, standard deviation, Simpson's index, stochastic frontier profit function and Ordinary Least Squares (OLS) regression analysis. Result showed that the Simpson index measuring the level of fragmentation was 0.54. The average farm size cultivated by the arable crop farmers was 2.33 ha. The mean cost of labour, seed, cuttings, fertilizer, pesticides and herbicides were ₦35987.01, ₦8020.77, ₦14044.44, ₦16198.04, ₦10500.00, and ₦7400.00 respectively; while the mean capital consumption allowance was ₦11348.06 and the mean value of output was ₦249601.2. The significant variables influencing farm profit were farm size ($P < 0.001$), normalized prices of labour ($P < 0.001$), planting materials ($P < 0.010$), and fertilizer ($P < 0.001$), and capital ($P < 0.001$). The significant determinants of the economics efficiency of the arable crop farmers were years of education ($P < 0.001$), household size ($P < 0.005$), farming experience ($P < 0.001$), extension contact ($P < 0.001$), and degree of land fragmentation ($P < 0.001$). The result showed that the individual economic efficiency indices range from 0.41to1.00 with mean of 0.778. The coefficient of fragmentation had negative and significant effect on output at 5% level of significance, farm size (at 1% level of significance level) and economic efficiency (at 1% level of significance level). For increased productivity and efficiency, farm consolidation programmes was therefore advocated as land fragmentation increases capital costs, labour demand and restrictions on the possibilities of agricultural mechanization.

KEYWORDS: Land, Fragmentation, Input Use, Yield, Production, Efficiency

1. INTRODUCTION
Land is an important resource for food, shelter and clothes. It is an essential natural resource, both for the survival and prosperity of humanity and for the maintenance of all global ecosystems (FAO, 2014). It is a basic resource for agricultural production. Majority of the population in sub-Saharan African countries like Nigeria live in rural areas and they depend on arable crop production as their major source of livelihoods. Arable farming entails the production of wide range of food crops or annual crops. This entails crops in which the life cycle is within one year; from germination to seed production and maturity. Arable crops included yam, maize, cocoyam, cassava, among others. The increase in food prices and food insecurity in various homes is not unconnected with the challenges facing arable crop production in the rural areas (Enete and Ubokudom, 2011).

Arable crop farming is subjected to various challenges ranging from scarcity of land and poor soil fertility, natural hazards, soil degradation, pests and diseases infestation, variations in rainfall and temperature, among others. Land fragmentation has been observed to have serious direct impact on agricultural production, because of the land-dependent nature of agricultural production systems (Enete and Ubokudom, 2011). They noted that the impact is particularly significant in developing countries like Nigeria where agriculture is the main source of income, employment and livelihoods for majority of the population.

Land fragmentation is the practice of farming a number of spatially separated plots of owned or rented land by the same farmer. It is a phenomenon which exists when a household operates a number of owned or rented non-contiguous plots at the same time as a single production unit (McPherson, 2014; Dovring and Dovring, 2009; Wu *et al*. 2005; Bentley, 1987). The existence of fragmented landholdings is regarded as an important feature of less developed agricultural systems. It can be a major obstacle to agricultural mechanization, causing inefficiencies in production of arable crop and involves large cost to alleviate its effects (Niroula and Thapa, 2007). Rahman and Rahman (2009) reported that land fragmentation has a significant detrimental effect on productivity and efficiency. According to Shuhao (2010) and Jha *et al.*, (2005), land fragmentation leads to increased travelling time between fields, hence lower labour productivity and higher transport cost for inputs and outputs. They noted that fragmentation also involves negative externalities such as reduced scope for irrigation, soil conservation investments and loss of land for boundaries and access routes.

Land fragmentation could result basically from either voluntary or involuntary choices by the farmer. According to Olarinre and Omonona (2018), voluntary choices which are demand driven are conditions or forces from outside or circumstances that may force the farmer to scatter or sub-divide his parcels. This can be done in order to acquire some financial gain majorly due to poverty index and need to go for specialized crop production on fragmented plot due to soils with different soil quality or fertility.

Involuntary choices are internal factors that the farmer has very little or no control over and yet they lead to land fragmentation. This is exemplified by inheritance and customary practices that forces people to divide their holdings or purchase additional holdings in attempt to achieve equitable distribution of properties among their heir as customs demands, increasing population densities across the world that puts a lot of pressure on the available land leading to land scarcity (Olarinre and Omonona, 2018; World Bank, 2015; Wadud and White, 2010).

Failure of land markets and state laws can also be a major cause for land fragmentation, where the transaction on land is restricted by law. This can have negative effect on the land consolidation policy. Obonyo (2015) noted that the nature of the landscape is one of the reasons for land fragmentation on the supply-side. Specifically, the boundaries such as waterways and wastelands allow the acquisition of separate pieces of land on either side of the natural boundaries leading to land fragmentation.

Customary tenure in cultures, where it is the responsibility of a father to divide his holdings equally among his sons, the problem of sub-division might become so severe and promote excessive fragmentation which is a drawback to land reform policy and impediment to agricultural development because of inefficiencies involved in owning a small unit vis-a-vis the modem agricultural techniques (Obonyo, 2015).

Results from research on the negative effects imposed by land fragmentation on productivity and efficiency in agriculture are mixed, (Rahman and Rahman, 2009). Blakie and Sadeque (2000) argue that land fragmentation is becoming a serious limit in increasing wheat productivity in Nepal, India and other nearby regions. On the contrary, in Malaysia and Philippines high land fragmentation is not considered an impediment in paddy farming (Niroula and Thapa, 2005, cited in Obonyo, 2015). This goes long way to prove that as much as land fragmentation affects the food security, it is entirely not a negative factor hence should be considered on both sides by authorities when making decisions over the land.

Land fragmentation is more often believed to be one major problem existing in rural land management, especially in developing countries (Balogun and Akinyemi, 2017). Land fragmentation besides the positive effects causes many negative effects including inefficiencies and higher costs i.e. extra labour costs, more fuel inputs for travelling between one plot to another plot, more wastages due to increased leakages and evaporation of fertilizers, water, pesticides, when applied to smaller parcels of land as compared to when used on one single holding (Balogun and Akinyemi, 2017). Increased negative externality such as reduced scope for irrigation and soil conserving investments, access routes, loss of land due borders and greater possibilities for disputes between neighbouring farmers (Balogun and Akinyemi, 2017).

Africa with a huge potential to feed itself requires sustainable and efficient utilization of resources in order to increase agricultural productivity thus addressing persistent food security threat in the region. It is argued that that there are only two possible options left to increase food production; either increase yield per hectare or expand the amount of land to be cultivated or both (Hofstrand, 2012). Expansion of agricultural land area is, however, not feasible technically since arable land is limited; the latter remains the only viable option. Increasing productivity could, however, further pose a major environmental threat since most technologies adopted often involve intensive input application, including fertilizers and agro-chemicals, which may impact negatively on the environment.

According to Iheke (2010), the concept of efficiency is concerned with the relative performance of the processes used in transforming given inputs into output. The analysis of efficiency is generally associated with the possibility of farms producing a certain optimal level of output from a given bundle of resources at least cost. Efficiency is achieved either by maximizing output from given resources or by minimizing the resources required for producing a given output (Varian, 2014). Production efficiency is the product of technical and allocative efficiencies. Technical efficiency is the ability of a farm to maximize output for a given set of resource inputs while allocative efficiency refers to the choice of optimum combination of inputs consistent with the relative factor prices (Iheke and Nwanyanwu, 2017).

Efficiency is the ability of a firm to achieve potential maximum profit, given the level of fixed factors and prices faced by the firm (Ambali1, *et al.,* 2012). Aigner *et al*. (1977) however, showed that profit function models do not provide a numerical measurement of firm-specific efficiency and popularised the use of the translog production frontier approach. The stochastic frontier approach has gained popularity in firm- specific efficiency studies (Ambali1 *et al.,* 2012).

Example of recent application includes (Ali *et al*., 1994; Ambali1, *et al.*, 2012, Iheke and Nwanyanwu, 2017; Iheke, 2010; Iheke *et al.*, 2013; Iheke and Onyendi, 2017).

From the foregoing therefore, it has become necessary and indeed pertinent to evaluate the effect of land fragmentation on input use and production efficiency among arable crop farmers in Ihiala Local Government Area of Anambra State, Nigeria. The study is justified by the fact that despite the plethora of works on land fragmentation and efficiency, none has dwelt on the subject matter in the study area. This information generated would aid the policy makers, governmental and non -governmental organization to design and develop effective sustainable land management strategies and policies for improved agricultural productivity and efficiency. This study specifically estimated the degree of land fragmentation, examined the input use of the farmers and their level of output, determined the production efficiency of the farmers and the factors influencing it, and examined the effect of land fragmentation and other factors on input use and yield.

2. METHODOLOGY

This study was conducted in Ihiala Local Government Area (LGA) of Anambra State, Nigeria. Ihiala is located between Longitude $6^{o}70^{1}$ and $6^{o}65^{1}$ North of the Equator and Latitude $6^{o}20^{1}$ and $6^{o}30^{1}$ east of the Greenwich Meridian (Microsoft Encarta, 2009). The population of the state according to the National Population Commission (NPC, 2006) was 188,060 and an estimate of 400, 000 persons (NBS, 2016). The annual relative humidity is 75% reaching 85% in the rainy season. The vegetation of the area is rainforest type with annual rainfall ranging from 2000 mm – 3000 mm and temperature ranging from 22ºC and 35ºC. The majority of the inhabitants of the town are farmers mainly of subsistent type while others were civil servants, traders, and other professionals. Arable and cash crops are cultivated, with livestock kept on small scale basis.

All arable crop farmers in Ihiala Local Government Area of Anambra State, Nigeria comprised the sampling frame for the study. Multi-stage random sampling techniques was adopted in selecting a sample of 90 respondents. In the first stage, 3 communities from Ihiala L.G.A (Uli, Okija, Azia) were purposively selected. These communities were selected based on the population of arable crop farmers in the area, as gotten from the State Agricultural Development Programme. In the second stage, 3 villages were randomly selected from each of the three (3) communities, making a total of nine (9) villages. Ten (10) arable crop farmers were randomly selected from each of the nine (9) selected villages in the final stage, giving total 90 arable crop farmers for the study.

Primary data were used for this study. A well-structured questionnaire was used to obtain information from the selected respondents. Of the 90 questionnaire distributed, 86 were retrieved and used for the analysis. Data collected included those of age, sex, marital status, household size, education level, farming as primary occupation, years of farming experience, method of land acquisition, number of farm plots, average plot size, distance of farmland, extension visit, cooperation, problems encountered in farm operations, amount of credit and farm input such as cost of seeds, labour, fertilizer, agrochemicals, rent, farm implements and their number and costs, etc. and prices of farm output.

The analytical tools employed for this study were descriptive statistics, Simpson's index, net farm income formula, multiple regression analysis and stochastic frontier production function. With respect to measuring the degree of fragmentation, the Simmons Index of Simmons (1964), the Januszewski Index of Januszewski (1968) and the Simpson Index of Blarel *et al* (1992) are among the most commonly used fragmentation indices in the literature. None of these indices is superior to one another; they are essentially similar to each other and incorporate the same three parameters desirable in assessing the degree of fragmentation: farm size; number of plots; and the size of plots. The choice of index for this study is the Simpson Index. The Simpson Index is defined as the sum of the squares of the plot sizes, divided by the square of the farm size.

$$\text{SI} = \frac{\sum_{i=1}^{n} a_i^2}{A^2} \qquad (1)$$

Where SI is the fragmentation index, n is the number of parcels belong to a holding, a is the size of a parcel and A is the total holding size. An SI value of 1 means that a holding consists of only one parcel and values closer to zero mean higher fragmentation.

The production efficiency of the farmers it in the study area will be analysed using economic (profit) efficiency. The economic efficiency was analyzed using the Cobb-Douglas profit function. It is given by:

$$\ln\Pi^* = \text{In}\beta_0 + \beta_1\text{In}P^*_1 + \beta_2\text{In}P^*_2 + \beta_3\text{In}X_3 + \beta_4\text{In}X_4 + V_1 - U_1 \qquad (2)$$

Where ln = the natural logarithm, Π^* = normalized profit, βo = constant term, β_1 - β_4 = regression coefficients, P^*_1 = normalized price of fertilizers; P^*_2 = normalized price of labour; X_3 = farm size (ha); X_4 = capital inputs in naira; V_i is a symmetric error accounting for the effect of random variations in output due to factors beyond the control of the farmer e.g., weather, diseases outbreaks, measurement errors, etc. Vi is assumed to be independently and identically distributed as N (O, δv_2) random variables independent of the U_is which is a non-negative random variable representing inefficiency in production relative to the stochastic frontier. The U_is are assumed to be non-negative truncations of the N (O, δv_2) distribution (i.e., half normal distribution) or have exponential distribution.

In order to determine the factors contributing to economic efficiency, the following model was formulated and estimated jointly with the stochastic frontier profit model in a single stage maximum likelihood estimation procedure using the computer software frontier version 4.1:

$$EE_i = [\exp(-U_i)] = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 + \delta_{10} Z_{10} + \delta_{11} Z_{11} \qquad (3)$$

Where EE_i= economic inefficiency effect of the ith farm; Z_1 = educational level of farmer in years of formal education completed; Z_2 = household size; Z_3 = sex of farmer (dummy; 1 = male, 0 female); Z_4 = age of farmer in years; Z_5 = primary occupation; Z_6 = years of farming experience; Z_7 = farm size (ha); Z_8 = credit access (dummy: 1 for access and 0 if otherwise);

Z_9 = Membership of association (dummy: 1 for membership and 0 if otherwise); Z_{10} = extension contact (numbers of contacts); Z_{11} = land fragmentation index; and δ_i = parameters to be estimated.

The effect of land fragmentation and other factors on input use and yield were analysed using the Ordinary Least Square regression model (OLS). The model is specified in the implicit form as:

$$Y = f(X_1, X_2, X_3, X_4, X_5 \ldots\ldots X_8) \quad (4)$$

Where Y = amount of inputs used (naira); X_1= land fragmentation index (number measured by Simpson index); X_2 = income (naira); X_3 = access to credit (amount of credit accessed in naira) X_4 = extension contact (dummy: contact = 1, 0 otherwise); X_5 = membership of co-operative (dummy: member = 1,0 otherwise); capital (depreciation, rent etc. in naira); X_6 = farming experience (years); X_7 = education attainment (years); and X_8 = farm size (ha^2)

$$Y = f(X_1, X_2, X_3, X_4, X_5 \ldots\ldots X_9) \quad (5)$$

Where Y = value of output (naira); X_1= land fragmentation index X_2 = farm size (ha^2); X_3 = labor cost (naira); X_4 = fertilizer (kg); X_5=capital (depreciation, rent etc. in naira); X_6 = extension contact (dummy: contact = 1, 0 otherwise); X_7 = membership of co-operative (dummy: member = 1,0 otherwise); X_8 = farming experience (years); and X_9 = education attainment (years).

Four functional forms of equations (4) and (5) namely: linear, exponential; semi long and double log function were fitted and the best fit model chosen for further analysis. The choice of the best fit model was based on the magnitude of the coefficient of multiple determination (R^2); the number of significant variables and the conformity of the signs borne by the coefficients of the variables to a priori expectations; and the significance of the F ratio.

3. RESULTS AND DISCUSSION

3.1 Degree of Fragmentation

The Simpson index (SI) was used to determine the degree of land fragmentation in the study area. The result showed an index of 0.54. This implies that there is still high level of fragmentation in the study area; a measure which if reversed by granting farmers access to contiguous farm holdings would lead to improved level of efficiency and productivity.

3.2 Input Use and Level of Output

The level of use of farm inputs and output produced are summarized and presented in Table 1

Table 1. Level of inputs and output

Variable	Mean	Standard deviation	Minimum	Maximum
Average plot size (ha)	2.33	1.81	0.4	4.5
Total labour (₦)	35987.01	95053.2	2000	53500
Seed (₦)	8020.77	1345.07	5750	15000
Cassava cuttings (₦)	14044.44	4474.55	9550	45000
Fertilizer (₦)	16198.04	3068.52	0	45000
Pesticide (₦)	10500.00	2543.63	0	31000
Herbicide (₦)	7400.00	9478.80	0	20000
Capital (₦)	11348.06	13271.19	710	16450
Output (₦)	249601.2	327139.9	75500	3150000

Source: Field Survey, 2019.

Table 1 showed that the average farm size cultivated by the arable crop farmers was 2.33 ha and the minimum and maximum were 0.4 and 4.5 hectares respectively, with a standard deviation of 1.81. Iheke (2010) reported a mean farm size of 2.73 and 1.98 hectares respectively for remittance receiving and non-receiving households. These farms despite being small were not contiguous farm holdings but fragmented, increasing the cost and time of moving from one plot to the other. This makes the drive towards farm mechanization difficult.

Table 1 further showed that the average amount spent on labour, seed, cassava cuttings, fertilizer, pesticides and herbicides were ₦35987.01, ₦8020.77, ₦14044.44, ₦16198.04, ₦10500.00, and ₦7400.00 respectively. These inputs are critical in agricultural production. According to Dome *et al. (*2015), higher input prices will increase total cost and as a result, farmers receive little output per hectare because of their inability to manage input costs. According to Mvodo-Meyo and Mbey-Egoh (2020), labour cost represents an integral part of production costs; production will be greatly affected by its variability. They asserted that in many instances, higher increase in labour cost has resulted in the inability of producers to cover functioning expenses.

Table 1 showed that there is increased used of fertilizer by the farmers as shown by the amount spent on fertilizer although there are farmers who did not use fertilizer. With declining soil fertility due to soil degradation and nutrient depletion, use of fertilizer and manure has been on the increase. The Food and Agriculture Organisation of the United Nations (FAO, 2005) reported that better fertilizer application implies an upwards shift in production and according to Byerlee *et al.* (1994), its low applicability results in low production, declining soil fertility and increase soil degradation through nutrient mining. Mvodo-Meyo and Mbey-Egoh (2020) reported that prices of variable inputs (fertilizers, labour and herbicides) are negatively correlated to maize production.

The mean capital cost (capital consumption allowance) was ₦11348.06 and the mean value of output was ₦249601.20. The average input cost was ₦103498.32. This implies that the farmers made a profit of ₦146102.88 (value of output less cost). The farmer operates at a profit if the value of output (total revenue) exceeds the total cost of production (sum of total variable and fixed costs).

3.3 Efficiency

3.3.1 Estimated profit function of the arable crop farmers

The maximum likelihood (ML) estimate of the stochastic frontier Cobb-Douglas profit function parameters for the arable crop farmers is presented in Table 2.

The estimated variance (δ^2) was statistically significant at 1 percent indicating the goodness of fit and correctness of the specified distribution assumptions of the composite error. Gamma (γ) was 0.869 and statistically significant at 1 percent. This implies that 86.9%percent of the variations in profit of the respondents are due to economic inefficiency.

Table 2. Estimated profit function of the arable crop farmers

Variable	Coefficient	Standard error	T-ratio
Intercept	11.698	1.092	10.716***
Farm size (X_1)	0.623	0.172	3.624***
Price of Labour (X_2)	-0.419	0.169	-2.477**
Price of planting material (X_3)	-0.329	0.204	-1.612*
Price of Fertilizer (X_4)	-0.055	0.016	-3.109***
Price of other agrochemical(X_5)	0.064	0.058	1.103
Capital (X_6)	0.392	0.036	10.782***
Diagnostic statistics			
Sigma squared	0.459	0.196	2.432**
Gamma	.869	0.321	2.7077***
Log likelihood function	-88.861		

Source: computed from Frontier 4.1/ Survey data, 2019.

The coefficients of the normalized prices of labour, planting materials, and fertilizer have the theoretically expected negative signs indicating that profit decreases with increase in the price of these variables, *ceteris paribus* for the arable crop farmers. This result conforms with the results of Mvodo-Meyo and Mbey-Egoh (2020), Iheke and Onyendi (2017) and Iheke (2010). Mvodo-Meyo and Mbey-Egoh (2020) noted that increase in input prices will reduce the quantity of inputs used production which ultimately results to low agricultural production; and this would lead to a concomitant decrease in farm profit. Similarly, high cost of inputs would lead to a reduction in profit since profit is the difference between value of output (revenue) and total cost of production.

The coefficients of farm size and capital were positively signed and significant indicating that increase in these variables would lead to increase in profit, *ceteris paribus.* Increase in farm size would lead to application of superior technology such as farm mechanization leading to increase output per unit of input and capital enables the farmer to purchase improved farm inputs and adoption of farm innovations for increased productivity. These would lead to increase in farm profits. These results are consistent with the findings of Iheke and Nwanyanwu (2017) who reported a positive and significant relationship between farm size, capital with profit.

3.3.2 Determinants of economic efficiency

Table 3 shows the result of the factors influencing the economic efficiency of the farmers. According to the Table, the significant determinants of the economics efficiency of the arable crop farmers were years of education, household size, farming experience, extension contact, and degree of land fragmentation.

Table 3. Determinant of economic efficiency

Variable	Coefficient	Standard error	t-ratio
Intercept	2.611	1.601	1.631*
Age (Z_1)	-0.011	0.101	-0.111
Education (Z_2)	0.123	0.043	2.860***
Household size(Z_3)	0.041	0.019	2.195**
Farming experience (Z_4)	0.330	0.103	3.199***
Cooperative (Z_5)	0.628	0.898	0.699
Extension contact (Z_6)	0.536	0.137	3.912***
Credit (Z_7)	-0.258	0.268	-0.964
Fragmentation (Z_8)	-0.411	0.182	-2.258**

Source: Computed from survey data, 2019.

***= significant at 1%; **= significant at 5%; and *= significant at 10%.

The coefficient of education had a positive coefficient and was significant at 1% level of significance. This implies that economic efficiency increases with increase educational attainment. Education enable farmers to be able understand new and adopt improved agricultural innovations and how best to combine the farm resources for improved productivity and efficiency. This result corroborates the findings of Iheke and Onyendi (2017), Iheke and Nwaru (2014), Iheke *et al.* (2013), and Nnadozie and Nwaru (2002).

The coefficient of household size was positively related to the economic efficiency of the arable crop farmers and significant at 5% level of significance. The result agrees with Oyetunde-Usman and Olagunju (2019) and Dipeolu and Akinbode (2008) and implies that the larger the household size, the more economic efficient the household would be, *ceteris paribus.* Large household size eases labour constraints at critical production period thereby leading to increase in productivity. Iheke (2010) reported that large household size provide cheap source of labour for farm work as farmers rely more on members of their households for labour which more predictable than hired labour.

The coefficient of farming experience was significant at 1% level of significance and positively related to economic efficiency. This implies that the more experience the farmer in farming, the more economically efficient he becomes. This conforms to *a priori* expectations. This result is consistent with the reports of Onubuogu *et al.* (2014), Nurudeen (2012), Onaiwu (2011) and Oluwataya *et al.* (2008) that farmers with more experience would be more efficient, have better knowledge of climatic conditions and market situation and are thus, expected to run a more efficient and profitable enterprise. According to Iheke and Nwankwo (2016) and Nwaru (2004), the number of years a farmer has spent in the farming business may give an indication of the practical knowledge he has acquired on how he can overcome certain inherent farm production problems and challenges.

The coefficient of extension contact was significant at 1% level of significance and positively related to economic efficiency. This implies that the higher the contacts with extension agents, the more economically efficient the farmer becomes. According to Nwaru *et al.* (2011), extension services provide informal training that helps to unlock the natural talents and inherent enterprising qualities of the farmer, enhancing his ability to understand and evaluate new production techniques leading to increased farm productivity and incomes with concomitant increase in the welfare of the farmer.

The coefficient of fragmentation was significant at 5% level of significance and negatively related to economic efficiency. This implies that he higher the fragmentation of farmland, the lower the economic efficiency. This result agrees with Dao (2013) who also reported a negative relationship between land fragmentation and efficiency but differs from the results of Balogun and Akinyemi (2017), Sherlund, *et al.* (2002), and Tan *et al.* (2010) that technical efficiency is higher for farmers who cultivate more plots than few. Gashaw *et al.* (2017), Deininger *et al.* (2014), and Kakwagh (2011) indicated that land fragmentation is often considered as the source of inefficiencies in crop productivity which is associated with production costs due to inefficient resource allocation; suboptimal usage of factor inputs that lowers overall returns to land due to losses on extra travel time, wasted space along borders, inadequate monitoring, and the inability to use certain types of machinery; hindering agricultural modernization and making it costly to modify adverse effects by consolidation schemes; and so forth. Empirically, they estimated that land fragmentation constitutes 60% of the total cash cost of production.

3.3.3 Distribution of efficiency

The efficiency distribution of the respondents is summarized and presented in Table 4.

Table 4. Distribution of economic efficiency of the arable crop farmers

Level of efficiency	**Frequency**	**Percentage**
0.41-0.60	14	16.28
0.61-0.80	27	31.40
0.81-1.00	45	52.33
Total	86	100.00
Mean	0.778	
Minimum	0.484	
Maximum	1.000	

Source: Computed from survey data, 2019.

Table 4 showed that the individual economic efficiency indices range from 0.41 to 1.00 with mean of 0.778. About 83.72% of the farmers have an economic index above 60 percent. The level of efficiency implies that ample opportunities exist for farmers to increase their efficiency for increased productivity.

3.4 Effect of Fragmentation on Output, Input use, and Efficiency

The effect of fragmentation on output and other variables is presented in Table 5. The result showed that the coefficients of multiple determination (R^2) were 0.7601. 0.8737, 0.7828, 0.8015, 0.4393, 0.2701, 0.6538, and 0.6716 for the output, farm size, labour, fertilizer, planting material, other agrochemical, capital, and efficiency functions, respectively. This showed that 76.01%, 87.375, 78.28%, 80.15%, 43.93%, 27.01%, 65.38% and 67.165 of the variations in output, farm size, labour, fertilizer, planting material, other agrochemical, capital, and efficiency of the farmers respectively, was explained by land fragmentation. The F ratios were all statistically significant indicating the goodness-of-fit of the model.

The coefficient of fragmentation had negative and significant effect on output at 5% level of significance, farm size (at 1% level of significance level) and economic efficiency (at 1% level of significance level). This result implies that increase in land fragmentation would lead to decrease in output, farm size and economic efficiency of the arable crop farmers. This result is consistent with Gashaw *et al.* (2017), Balogun and Akinyemi (2017), Iheke ans Amaechi (2015), Austin *et al.* (2012), and Kakwagh *et al.* (2011). They reported a negative relationship between fragmentation and output, farm size, and efficiency. However, this result is in contrast with Paul and wa Gĩthĩnji (2018) who reported a positive relationship between fragmentation and output.

On the other hand, the coefficient of fragmentation was significant and positively related to labour, fertilizer, and agrochemicals. This implies that increase in the degree of fragmentation would, ceteris paribus, lead to increase in the use of labour, fertilizer and agrochemicals. This implies that fragmentation hinders the efficiency of resource use. This conforms with the reports of Gashaw *et al.* (2017), Deininger *et al.* (2014), and Kakwagh (2011).

Table 5. Estimated effects of fragmentation of output and other variables

Output	**Coefficient**	**t-ratio**	**R^2**	**R^{-2}**	**F-ratio**
Intercept	525149.9	4.19***			
Fragmentation	-92186.11	-2.32**	0.7601	0.7089	9.28***
Farm size					
Intercept	1.286	-19.85***			
Fragmentation	-0.864	-4.20***	0.8737	0.8138	17.65***
Labour					
Intercept	29.2111	9.82***			
Fragmentation	46.36326	4.89***	0.7828	0.7290	10.99***
Planting material					
Intercept	7384.947	2.51***			
Fragmentation	333.8759	0.36	0.8015	0.7504	12.81***
Fertilizer					
Intercept	25037.02	3.46***			
Fragmentation	4254.354	1.85*	0.4393	0.3579	3.44***
Agro-chemical					
Intercept	9234.613	1.83*			
Fragmentation	157.8978	0.10	0.2701	0.2118	2.01**
Capital					
Intercept	17042.48	3.56***			
Fragmentation	2177.599	1.43	0.6538	0.6122	6.05**
Efficiency					
Intercept	0.8645442	17.65***			
Fragmentation	-0.756565	4.87***	0.6716	0.6103	8.88

Source: Computed from survey data, 2019.

4. RECOMMENDATIONS

Based on the findings of this study, it was recommended that land reform policies that will grant farmers access to large and consolidated farm holdings for improved productivity and efficiency should be implemented. Also, there is the need for agricultural input subsidy policies as this would enhance farmers' accessibility to production inputs, leading to increased productivity and access to food. There is equally the need to strengthen the extension delivery system in Nigeria as improved extension contact by farmers enhances their efficiency.

5. CONCLUSION

It could be concluded that land fragmentation reduces farm productivity and efficiency. Also, the level of efficiency recorded indicated that ample opportunities exist for the arable farmers to improve on their efficiency and productivity. It could equally be deduced from the study that land fragmentation increases capital costs, labour demand and restrictions on the possibilities of agricultural mechanization.

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ANALYSIS OF LEVEL OF AWARENESS AND ADOPTION OF NCAM MECHANICAL MELON SHELLER IN EDU L.G.A OF KWARA STATE

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ABSTRACT

The study analyzed the level of awareness and adoption of NCAM mechanical Melon Sheller in Edu Local Government Area of Kwara State Data were obtained through interview schedule with structured questionnaires using random sampling technique. A total of 60 melon processors across four villages were randomly selected and used for the study. Organization and description of data were done by the use of frequency distribution table, percentage, mean and sigma/adoption scoring method. The findings from the study (N= 60) indicated that majority (95%) of the melon processors in the study area were female, married (93.33%) and 70% with experience in melon processing. The result of the investigation on awareness creation of the melon sheller showed that about 98.3% were not aware of NCAM technologies before demonstration. After the demonstration was conducted for the processors, they preferred the NCAM melon sheller to the method they have been using before and 96.7% of the respondents were willing to use NCAM melon sheller. The adoption score of 5.96 shows high level of adoption of the technology in the study area.

KEYWORDS: Awareness, adoption level, melon sheller, processing technology.

1. INTRODUCTION

Melon (*Citrullus lanatus*) is an oil seed crops majorly grown and consumed in Nigeria and most other African countries. The melon seeds are small, flat and oval containing a white cotyledon in a thin walled shell with a thick ring around the edges (Adeniran and Wilson, 1981; Langer and Hill, 1998; Maynard, 2001).

Egusi (melon) is an essential crop in Nigeria and in some other Africa Countries, melon seeds are peeled and used in preparing assorted dishes, the ground seeds are used in seasoning food (Anuebunwa, 2000). In the Northern parts of Sudan, seeds of some types are eaten whole including the seed coat after being roasted (Achu *et al*., 2005). The melon seed kernel (Egusi) has been used as the basis for a number of soups where it results in thickening, emulsifying, fat binding and flavoring. It is also a raw material in the production of margarine, salad, "robo cake", baby food and livestock feeds. Its oil is used in the production of local pomade, soap and its shell is used as poultry litter (Shittu and Ndrika 2012; Achu *et al*., 2005).

In processing of melon, different unit operations include depodding, fermentation, coring, washing, drying, shelling and cleaning (Kushwaha *et al*., 2005). Traditional method of shelling melon is slow, time consuming, tedious, inefficient and involves drudgery, thus limiting the availability of the product in the market. This has given concern to scientists and researchers in the recent past, particularly since women are the major processors of melon especially at shelling stage. Though there has been some development in the mechanization of melon (egusi) shelling machines, the machines are unattractive to local farmers because of their sophistication and low output. According to Kassim *et al*. (2011), the locally fabricated melon shelling machines available in the market have low efficiencies, however, investigations and performance evaluation test carried out by the Agro Industrial Development and Extension Department on the improved melon sheller developed by the National Centre for Agricultural Mechanization (NCAM) have revealed that the developed machine has overcome the problems listed above and has a shelling efficiency of more than 80%.

The objectives of the study are:

i. To establish the level of awareness of NCAM mechanical melon sheller in Edu LGA;
ii. To determine the level of adoption of NCAM mechanical melon sheller in the study area.

2. METHODOLOGY

The study was conducted in Tsaragi, Ankoro, Patiduru and Baatain Edu LGA of Kwara State because they are majorly known for melon production and processing in large quantities. Edu is one of the Local Government Areas in Kwara State with an estimated total land area of about 2,542 km^2 and an estimated population of about 201,469 (NPC, 2006). The climate is characterized by dry and wet season. The annual rainfall ranges between 1000 and 1500mm. Average temperatures between 30°C and 35^{o}C and humidity range from 35 to 60%. Edu LGA has 8.8892^o N Latitude and 5.1432^o E Longitude. The major source of livelihood and occupation of the people in these areas is farming (KWSMI, 2002).

A total of 60 Agro- processors from the local government were randomly selected for the study. This formed the sample size of the study. The source of data used for this study was basically generated primarily. This involved the use of an interview schedule with structured questionnaires

The technology was demonstrated to the processors, after which the melon sheller was left for extensive use by the processors for two weeks. Data were collected on the level of awareness, level of adoption of NCAM mechanical melon sheller and the socio economic characteristics of the respondent through the use of structured questionnaires. Data obtained were analyzed using descriptive statistics such as frequency distribution table, percentages and means. The level of awareness of NCAM mechanical melon sheller and level of adoption of NCAM mechanical melon sheller were determined using sigma scoring method/adoption score. The following steps were used:

i. Obtain the percentage of processors who used the NCAM mechanical melon sheller (A) x 100 = A x 100 = A%
ii. This is followed by dividing the percentage (A %) by two and subtract the answer from 100;100 – (A%/2) = B%
iii. Check B% on the statistical table of normal deviates to get the sigma distance (X).
iv. Next, increase the value of the sigma distance using a constant figure of 2 and multiplying the result by the same constant.(X +2) x 2 = Y
v. Sigma method assigns weight in reverse direction on a 10 point scale, the actual sigma score would be 10 minus the answer (Y). 10 – Y = Z
vi. Decision Rule**:** Any mean score (Z) less than 5 is considered as low level of awareness/adoption.

3. RESULTS AND DISCUSSION

3.1 Socio-economic Characteristics of the Respondents

The social economic characteristics of the respondent are shown in Table1. The Table 1 shows that 95% of the respondent are females, indicating that the female gender are deeply involved in melon processing and as well be related to the socio-cultural factors that restricts gender in some communities (Arokoyo, *et al*. (2002). Table 1 also revealed that bulk of the respondents (93.33%) are married, while 5% and 1.67% were widowed and single respectively.

Table 1 further revealed that majority of the respondents (70%) had less than 10 years of experience in melon business. Those between 2-5 years of experience were 20% while those with more than 10 years were 10%.

Table 1. Socio-economic Characteristics of the Respondents

Gender	**Frequency**	**Percentage**
Male	3	5.00
Female	57	95.00
Total	**60**	**100**
Marital status		
Single	1	1.67
Married	56	93.33
Widowed	3	5.00
Divorced	0	0.00
Total	**60**	**100**
Melon processing experience (Years)		
<2		
2-5	12	20.00
6-10	42	70.00
>10	6	10.00
Total	**60**	**100**
Age (Years)		
<20	0	0.00
21-30	7	11.67
31-40	29	48.33
41-50	15	25.00
>50	9	15.00
Total	**60**	**100**

Source: (Field Survey, 2015)

3.2 Awareness of the NCAM Mechanical Melon Sheller

Table 2 shows the awareness distribution of the NCAM Mechanical Melon Sheller in the study area. From Table 2, it can be deducted that 98.3% of the melon processors in the study area were not aware of the NCAM mechanical melon sheller until the period of the demonstration

Table 2. Awareness Distribution of the NCAM Mechanical Melon Sheller.

Research Item	Frequency	Percentage (A%)	100-(A%/2)= B%	Sigma distance B% = X	Y=(X+2)x2	Actual sigma score Z =10-Y
Not Aware	59	98.3	50.85	0.02	4.04	5.96
Aware	1	1.7	99.15	2.39	8.78	1.22
Total	60	100				

From Table 3, it was observed that the responses of respondents on the use of the technology, after the demonstration was shown, 96.7% of the respondents were willing to use NCAM melon sheller for their melon shelling because of the effectiveness they got during the demonstration. While less than 4% were not willing.

Table 3. Frequency Table on Responses of Respondents on the use of NCAM Mechanical Melon Sheller

Research item	Frequency	Percent Usage
No	2	3.3
Yes	58	96.7
Total	60	100

3.3 Adoption distribution of the NCAM Mechanical melon sheller

Table 4 describes the adoption distribution of the NCAM Mechanical Melon Sheller in the study area. 98.3% of the respondents adopted the use of NCAM Melon Sheller. The result revealed that there was no difference in the responses of the respondents in all the villages due to chance of variation which implies that the respondents behave the same way. It is important to note that in any development activities, awareness of technology must be recognized according to Agwu *et al*. (2008).

Table 4. Frequency Table on Responses of Respondents on the Method to Adopt

Research item	Frequency	Percent Adopted
Other methods	1	1.7
NCAM Melon Sheller	59	98.3
Total	60	100

Source: (Field Survey 2015)

Table 5 shows that while 98.3% of the melon processors adopted the technology, 1.7% of them did not. The adoption score of 5.96 for processors who adopted the use of the NCAM mechanical melon sheller revealed high level of adoption of the technology in the study area. This agrees with the findings of Bello *et al*. (2012) and Adejoh *et al*. (2012).

Table 5. Adoption Distribution of the NCAM Mechanical Melon Sheller

Research Item	**Frequency**	**Percentage (A%)**	**100-(A%/2)= B%**	**Sigma distance B% = X**	**Y=(X+2)x2**	**Actual sigma score Z =10-Y**
Adopted	59	98.3	50.85	0.02	4.04	5.96
Not Adopted	1	1.7	99.15	2.39	8.78	1.22
Total	60	100				

Source: (Field Survey 2015)

4. CONCLUSION

From the study, it can be concluded and recommended that

1. The level of awareness improved at the end of the demonstration of NCAM Melon Sheller prior to what the processor observed before the demonstration.
2. High percentage of the processors adopted the use of the technology probably because it is easy to operate and maintain since majority of the processors are women.

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CHARACTERIZATION OF SOME ANIMAL RESIDUES AS POTENTIAL ALTERNATIVES TO FOSSIL FUELS AND SOIL AMENDMENTS

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ABSTRACT
The aim of this study is to perform a comparative study on some selected animal residues in order to explore their potential as alternative sources of energy and soil amendments. Agricultural residues are potential deposits and reservoir of energy vectors that could be used as renewable energy sources if harnessed for economic purposes. Average annual livestock residue in Nigeria was estimated at 105,007 Mt most of which were left without meaningful and appreciable economic viable management policy. The multiplication of livestock farming and aggravated accumulation of crop residues after harvest stimulates increased emission of greenhouse gases during decomposition and burning thereby encouraging rise in average global temperatures and increased greenhouse effect. Four livestock residues wastes were evaluated for their yield potentials of CH_4, CO_2, *and* N_2O*at an ambient temperature (*28^OC*). Both physical and chemical compositions of the residues were determined using standard laboratory procedures after drying at* 77^OC*. Percent by mass (Pm), molar compositions (Mc); molar ratios (Mr.), air requirements for oxidation (Ar), chemical formulae (Cf), energy content (Ec) and potential volume of methane (Pv) available for harvest were evaluated using empirical models. Results obtained showed that poultry manure has the highest percentage of* CH_4 *(15.51%); pig has the highest percentage of* CO_2 *(16.62%); the N obtained for all the manures were similar, while the* N_2O *was insignificant to make any meaningful difference. The results also shows that, horse manure has the highest percentage of 8.03% K while the amount of N, and P are similar for all the manures tested, suggesting suitable alternative composting sources for soil amendment. Overall result shows that poultry manure has the best potential energy value of 45.852 Kj/Kg.*

KEYWORDS: Characterization,

1. INTRODUCTION

The potential alternative energy sources for the rural agricultural sector are biomass. Enormous volumes of agricultural wastes in form of livestock manure, crop residues, agro-industrial wastes and human excreta are littered in the environment causing severe environmental pollution. If properly managed, such residues could be converted into potential sources of energy that could be ploughed back into agricultural production and processing activities (Onyema, 2010).

Applying animal residues as alternative source of inorganic fertilizers has gradually declined due to several factors. Primarily, cattle rustling, separation of crop and livestock production, and increased availability and dependence on synthetic fertilizers were the influencing factors (Akyurek, 2018). Studies have shown that besides polluting the environment, use of commercially available synthetic fertilizers degrade the quality of the soil overtime (Akyurek, 2018). The increasing effects of synthetic fertilizers and improperly treated animal wastes on the environment and human health made researches on alternative source of energy and soil amendments inevitable (Demirbas, 2009). Animal residues are known for supplying nutrients for crop production and organic matter which in turn improves soil structure, water holding capacity, drainage, reduces wind and water erosion, provides a source of slow release nutrients, and promotes growth of earthworms and valuable microbes for crop production (Akyurek, 2018). Animal residues have been considered as a potential fertilizer throughout the millennia. Such residues were known to contain essential macro- and micro-nutrients for crop effective growth and as a cost-effective alternative to inorganic fertilizers. They also have various uses such as fuel source, disinfectant, purifier, insects repellent (Demirbas, 2009).and a valuable feed for earthworms in vermicomposting process (George and Frank, 2002 and Howard *et al.*, 1985). The relationship between the feed and the animal excreta has been established by many researchers (Isci and Demirer, 2007; Gerrit, 2020; Kashyap *et al.*, 2003 and Sujatha and Alison, 2014). The properties of such residues depend on several factors: animal species; diet, digestibility, protein and fiber content; and animal age, housing, environment, and stage of production.

Previous studies shows that animal residues can be transformed into resources for composting or soil amendments in crop production, raw materials for industrial operations and energy generation when adequately and sustainably harnessed. Tchnobanoglous *et al.* (2002) opined that the most effective way of managing animal residues is by reducing of the amount and the toxicity entrenched. Interestingly, as people search for better life and higher standard of living, more products are consumed with resultant higher degree of waste generation. Notwithstanding the perceived menace and potentials of the animal residues, more complex resolution were required before concerted efforts are put in place for their utilization. Available literatures on the use of animal residues for energy production in Nigeria (especially biogas energy) compared the potentials of other animal residues with energy crops in terms of C/N ratio (George, and Frank, 2002). Most animal residues still remained the most untapped bio fuel (Akyurek, 2018, Isci and Demirer, 2007). Conventionally, the annual average amount of livestock residue in Nigeria was estimated at 105,007 Mt without adding significant national economic viable management policy for utilization. This study is aimed at characterizing the potentials of some selected livestock residues (Cow, Horse, Poultry and Pig) as viable alternative sources of energy and soil amendments for the rural household and enhanced crop production.

2. MATERIALS AND METHODS

This study was conducted in the Processing Laboratory of the Department of Agricultural and Bio-Resources Engineering, Ahmadu Bello University, Samaru-Zaria. Samaru lies within latitude 11°11’N and longitude 7° 38’E at an altitude of about 686m above mean sea level. The climatic condition of Samaru is characterized by an annual mean rainfall of 1000 mm, atmospheric humidity as low as 15% during the dry season and above 60% during the wet season. The minimum and maximum temperatures of 22˚C in January and 28˚C in the month of April (Akhtar *et al.*, 2013).

Four livestock residues components comprising Cow, Horse, Poultry droppings and Pig wastes were collected within Samaru and evaluated for their yield potentials of CH_4, CO_2, and N_20 at ambient temperature. Moisture content of the livestock residues expressed as the mass of moisture per unit dry material was obtained by drying in an oven at (Heraeus/Hanau) at 60°C for 12 h to a constant weight and their respective moisture contents were determined using Equation (1) as suggested by Ekebafe *et al*. (2012):

$$Mc\ (\%) = \frac{\text{Wsbd}-\text{Wsad}}{\text{Wsad}} \times 100 \quad (1)$$

` where,

Mc = $Moisture\ Content$,%;
$Wsbd$ = $Weight\ of\ Sample\ before\ drying$, g;
$Wsad$ = $Weight\ of\ Sample\ after\ drying$, g

Both proximate and ultimate compositions of the samples were determined using standard laboratory procedures to determine the level of nitrogen and carbon concentrations obtainable for possible composting after digestion for methane production. Percent by mass, molar composition, molar ratio were determined based on the model developed by Howard *et al.* (1985). Appropriate chemical formula with or without sulphur was obtained based on the ratio of the molar mass of each sample to the moles of sulphur and nitrogen where the moles were calculated on the mass of each element to the atomic mass of the sample. Energy content of samples were determined using Dulong formula:

$$kj/kg = 337C + 1428\ (H\text{-}0/8) + 9S \qquad (2)$$

where,

C = Carbon,
H = Hydrogen,
O = Oxygen
S = Sulphur percent.

Energy content was evaluated using equation (3) as kj/kg (ash-free dry basis) =

$$kj/kg\ (\text{as discarded}) \left(\frac{100}{100 - \%\ ash - \%\ mc}\right) \qquad (3)$$

where mc is percent moisture content, assuming the ash content is = 5.0% (Howard *et al.,* 1985). The samples' moisture contents were converted to hydrogen and oxygen following the computation model of Howard *et al.* (1985). The chemical formulae of the samples were determined based on the conversion trend with and without sulphur.

Air requirements for complete oxidation of one tonne of each sample were calculated using equation (iv) based on the chemical compounds estimated.

$$CaHbOcNd + \frac{4a+b-2c-3d}{4} O_2 \longrightarrow aC02 + \frac{b-3d}{2} H_2O + dNH_3 \qquad (4)$$

where a, b, c and d are coefficients of C.H.O. and N.

The overall anaerobic conversion of organic wastes occurring in three phases such as liquefaction, bacterial conversion into lower molecular weight intermediate compounds and bacterial conversion of the intermediate compounds into end products like CO_2 and CH_4 was expressed by equation (5) as:

$$CaH_bO_cN_d \longrightarrow nC_wH_xO_yN_z + mCH_4 + sCO_2 + rH_2O + (d\text{-}nz)\ NH_3 \qquad (5)$$

where, s = a – nw – m; r = c – ny – 2s with the assumption of complete conversion to CO_2 and CH_4 (Howard *et al,* 1985). Potential volume of methane gas expected from the anaerobic digestion of a tonne of samples based on equation (6) was determined using as:

$$C_a H_b O_c N_d + \frac{4a-b-2c+3d}{8} H_2O \longrightarrow \frac{4a+b-2c-3d}{8} CH_4 + \frac{a-b+2c+3d}{8} CO_2 + dNH_3 \quad (6)$$

where a, b, c and d are co-efficient assuming 0.7167 kgm^{-3} and 0.85 as the density of methane and actual volume of gas for production respectively.

3. RESULTS AND DISCUSSION

Results for the chemical composition of the selected livestock samples are presented in Table 1. The degree of variation in composition is very minimal possibly showing residues of similar soil amendments potentials. However, C/N ratio shows 33:1, 37:1, 28:1 and 28:1 for Hs, Cw, Po and Pg respectively confirming the superiority of Po and Pg over other livestock residues in terms of C/N ratio in contrast to the report of Akyurek, 2018, Isci and Dermirer (2007), which could be attributed to the variation in C content. Similarly, Hs recorded the least C concentration and next to the lowest H^+ (Table 1), while Po with the highest moisture content dry basis, produced the highest H^+, showing the greatest possibility of aerobic digestion of methane, the highest potential for fertilizer in terms of percent N and next in evolution of S to Pg. Table 2 presents the mass and percent by mass components of the combined livestock residues when mixed together.

Table 1. Composition of some livestock residues

Livestock	Dry mass used for analysis (kg)	C	H	O	N	S	MC
		(%)					
Horse	0.05	0.99	0.103	**0**.062	0.03	0.037	13.87
Cow	0.05	1.12	0.098	0.056	0.03	0.0194	17.03
Poultry	0.05	1.12	0.130	0.070	0.04	0.030	35.25
Pig	0.05	1.12	0.112	0.06	0.04	0.044	4.98

Table 2. Composition of the cumulative components of some residues

Component	Mass (kg)	Percent by mass (%)
Moisture	69.13	-
C	4.35	5.9
H	0.443	11.0
O	1.310	83.0
N	0.14	0.19
S	0.13	0.18

Oxygen exhibited the highest percent by mass which possibly suggests the presence of stoichiometric amount of oxygen required for combustion of the residues. Tables 3 and 4 show the molar compositions and molar ratios of the residues under combined formulation with the chemical formulae with or without sulphur as $C_{90}H_{2010}O_{960}S_{1.0}$ and $C_{36}H_{804}O_{384}N_{1.0}$. Similarly, Table 5 reflects the percent by mass of the individual livestock residue showing Po as the highest in C, H, O, N and Pg the highest in S concentrations respectively. Both the molar compositions and the molar ratios of each livestock residues are shown in Tables 6 and 7. The values were not consistent as Cw gave the highest for C, Hs, for H^+, Po for O and Hs for S. This trend is however expected in view of the different nutrient dynamics typical of the rations specific to different livestock. However, based on the molar ratio without sulphur, the chemical formulae evaluated for Hs, Cw, Po and Pg were Hs =$C_{38.1}$ $H_{49.0}$ $O_{1.91}$ N; Cw =$C_{42.9}$ $H_{44.8}$ $O_{15.2}$ N; Po= C_{31} H 44.8 $O_{15.2}$ N and Pg = C_{31} H 38.6 $O_{1.3}$ N respectively with Hs exhibiting the highest H^+ followed by Cw and Pg the least (Table 8). The theoretical air requirement to completely oxidize one ton of both combined livestock residues and individual residues are shown in Tables 9 and 10 with the assumption of percent oxygen in the air as 23.13%, density of air as 1.2928kgm^{-3}, density of methane as 0.7167kgm^{-3} and the actual value due to synthesis of cell tissue as 0.85 (Howard *et al*, 1985). Although, the theoretical cumulative energy values generated by the individual residues was 55.6 percent greater than the combined. However, the theoretical air requirements to completely oxidize one ton of the individual residues were correspondingly 15.6% higher than the combined. Similarly, the theoretical volume of methane expected under the combined formulation was 66.4 m^{3}t^{-1}compared with 3,547.2 m^{3}t^{-1} observed in the cumulative addition of individual residues.

Table 3. Molar compositions of the different components

Components	**Mass (kg)**	**kg/mol**	**Moles**
C	4.35	12.01	0.36
H	8.12	1.01	8.04
O	61.45	16.0	3.84
N	0.14	14.01	0.01
S	0.13	32.06	0.004

Table 4. Mole ratios of the different components

Element	**Sulfur**	**Nitrogen**
C	90.0	36.0
H	2010	804
O	960	384
N	2.5	1.0
S	1.0	0.4

Table 5. Percent by mass of the different elements in the livestock waste

Waste	**C**		**H**		**O**		**N**		**S**	
	mass (kg)	**% by mass**	**mass (kg)**	**% by mass**	**mass (kg)**	**% by mass**	**mass (kg)**	**% by mass**	**mass (kg)**	**% by mass**
Horse	0.99	22.75	0.13	23.3	0.062	25.0	0.03	21.4	0.037	28.46
Cow	1.12	25.75	0.098	22.1	0.056	22.6	0.03	21.4	0.019	14.62
Poultry	1.12	25.75	0.130	29.3	0.070	28.2	0.04	28.6	0.030	23.08
Pig	1.12	25.75	0.112	25.3	0.060	24.2	0.04	28.6	0.044	33.85
Total	**4.35**	**100**	**0.47**	**100**	**0.248**	**100**	**0.14**	**100**	**0.13**	**100**

Table 6. Molar compositions of the elements in livestock wastes

Waste	C	Kg/mol	mole	H	Kg/mol	mole	O	Kg/mol	mole	N	Kg/mol	mol	S	Kg/mol	mole
Horse	0.99	12.01	0.08	0.103	1.01	0.103	0.062	16.0	0.0040	0.03	14.01	0.0021	0.037	32.06	0.0012
Cow	1.12	12.01	0.09	0.098	1.01	0.098	0.056	16.0	0.0035	0.03	14.01	0.0021	0.019	32.06	0.0006
Poultry	1.12	12.01	0.09	0.130	1.01	0.130	0.070	16.0	0.0044	0.04	14.01	0.0029	0.030	32.06	0.009
Pig	1.12	12.01	0.09	0.112	1.01	0.112	0.060	16.0	0.0038	0.04	14.01	0.0029	0.044	32.06	0.0014

Table 7. Molar ratios of the elements in livestock residues without sulfur

Residue-	C	MR	H	MR	O	MR	N	MR	S	MR
Horse	0.08	38.1	0.103	49.05	0.004	1.9	0.0021	1.0	0.012	0
Cow	0.09	42.9	0.098	46.7	0.0035	1.7	0.0021	1.0	0.006	0
Poultry	0.09	31.0	0.130	44.8	0.044	15.2	0.0029	1.0	0.009	0
Pig	0.09	31.0	0.112S	38.6	0.0038	1.3	0.0029	1.0	0.0014	0

Table 8. Chemical Formulae

Horse	-	$C_{38.1}H_{49.0}O_{1.91}N$
Cow	-	$C_{42.9}H_{46.7}O_{1.7}N$
Poultry-		$C_{31}H_{44.8}O_{15.2}N$
Pig	-	$C_{31}H_{38.6}O_{1.3}N$

Table 9. Air requirements to oxidize completely 1 tonne of combined Horse, Cow, Pig and Poultry waste with chemical equation $C_{36}H_{804}O_{384}N_{1.0}$

Mass of air required kg/t	Vol. of air required m_3/t	Oxygen required kg/t	Mass of methane kg/t	Vol. m_3/t
3327.9	2573.78	770.29	47.6	66.4

Table 10. Air requirements to oxidize completely 1 tonne of livestock Residues and methane production

Residue	Mass of Air reqd. kg/t	Vol of Air reqd. m^3/t	Oxygen required kg/t	Mass of methane kg/t	Vol. of methane m^3/t
Horse	12,713.6	9,834.14	2943.19	706.74	986.10
Cow	12,553.74	9,710.5	2906.19	719.9	1,004.5
Poultry	14,000	10,830	3,240	410.5	572.7
Pig	12,755.5	9,866.6	2952.9	705.2	983.9

Generally, the mass of air required for the production of methane was highest under Pg and lowest under Hs. Correspondingly, the theoretical volume of methane produced was highest under Cw with the lowest mean volume of air while the highest energy value was obtained under Po at 45,852.0kj/kg (Table 11). However, it is interesting to observe that ionic number of carbon and oxygen in the chemical formula of the residues played a significant role in potential volume of methane obtainable for production. Cw with chemical formula $C_{42.9}$ H $_{44.8}$ O $_{15.2}$ N exhibiting the highest ionic number of carbon and oxygen recorded the highest volume of methane. Overall result suggests that Cw was more preferable for methane production among the livestock residues investigated, although, in terms of energy value, Po appeared the best.

Table 11. Energy content (Heating value) of the livestock wastes

Residue	**Energy content kj/kg**
Horse	35,179.2
Cow	36.350.7
Poultry	45,852.0
Pig	41,031.05

4. CONCLUSION

Livestock residue keep increasing on daily basis which suggests a positive correlation between livestock and waste accumulation. Increased agricultural activities in livestock husbandries encourage aggravated increase of leachates, effluents and solid wastes with life threatening and toxic build-up because the resultant wastes are left to decompose freely with evolution of greenhouse gases. Therefore, the greater the accumulation of these gases without conversion to useful products, the greater the tendency for more heats than needed to be trapped thereby making the earth less comfortable for humans, plants and animals. Moreover, climate effect and the attendant issues that seem to defile solution in addition to consistently diminishing natural resources like fossil fuels, surface and underground water pose a great danger to local, national and international survival.

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MECHANIZATION LEVEL OF CASSAVA PROCESSING IN CROSS RIVER STATE, NIGERIA

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ABSTRACT
Cassava is a crop that is of great importance in Nigeria. The Nigerian government of Buhari-Osinbajo led has shown concerns about diversifying the country's economy, and agriculture is one of the major sectors considered for the diversification of the economy. The National Centre for Agricultural Mechanization (NCAM), Ilorin, for this sole purpose in 2018 carried out a National Mechanization survey exercise in Cross River State to ascertain the present level of agricultural mechanization obtainable for cassava processing, to identify areas in the processing operation of cassava roots into various products like garri and flour that needs urgent attention in the State. The Snowball technique of data collection was used to identify active cassava processing centres and structured questionnaires were administered to the respondents in the study areas. Descriptive statistical analysis involving frequency counts and percentages in a Statistical Package for Social Sciences (SPSS) was used to analyze the data obtained. Survey results indicated that there are nine (9) cassava processing unit operations involved in the processing of cassava roots into various products; cassava peeling, washing and garification unit operations were dominated by manual processing methods with values of 98.25, 73.88 and 71.93% in all the cassava processing units visited in the State. It was also observed that the sum of 39.76% was recorded for the mechanical processing method for the nine (9) cassava processing unit operations such as grating, dewatering and milling operations resulting in this figure. This 39.76% value obtained for mechanical involvement for the processing of cassava in the State calls for urgent attention of the cross-river State government to increase the percentage of cassava processing machines used for cassava roots processing for each of the unit operations in the State. It is therefore concluded that cassava processing mechanization in the Cross River State of Nigeria at the time of this study, is marginally lower than manual processing. Therefore, technological innovations through sustainable agricultural mechanization training to farmers will offer great potential to enhance the cassava value chain through collaborations.

KEYWORDS: Cassava, Processing, Mechanization, Level

1. INTRODUCTION

Cassava (*Manihot esculenta*) is a staple root crop, rated among the most important crop in Africa. It survives a wide range of soils which can produce a high yield of cassava roots; cassava is consumed by over 500million African populace and served as a staple for 40% of the population in Africa (CTA, 2005). Cassava grows well in the west, east, central and South African countries due to its versatile nature as a result in it is been processed into a wide variety of different products. (Next GenCassava, 2013; Adenle *et al*., 2012; Kolawole *et al*., 2010).

Cassava plays a pivotal role in the agricultural economy of developing countries, especially in sub-Saharan Africa. It is a food security crop which is useful as both subsistence and cash crop. Cassava and its various allied products hold an important position in countries economies such as Nigeria and Ghana by positively affecting their gross domestic product, Nigeria is the highest producer of cassava globally (Ezedinma *et al*., 2007; Knipscheer, 2007; Taiwo and Fasoyiro, 2015).

Over the past years, cassava production in sub-Saharan Africa has risen significantly, however, most of the increases in overall production are associated with an increase in the area of land cultivated rather than an increase in yield (Ikuemonisan, *et al*., 2020; Spencer and Ezedinma 2017). However, Nigeria accounts for only 0.001% of the world cassava export and this poor performance in the world cassava export market has been severally attributed to poor and inadequate cassava processing technologies (Oyelade *et al.*, 2019).

According to Abdoulaye*et al.* (2014), the level of adoption of these cassava processing technologies has been reported as the major factor that can determine the output of cassava products and by-products.

Therefore, it is pertinent to investigate the level of our preparedness in promoting the export of cassava products to other countries. To achieve this, there was a need to conduct a National Mechanization survey exercise among agro-processors who are into cassava processing in Cross River State of Nigeria; this study, therefore, was aimed at investigating the present status of mechanization for cassava processing in Cross River State, major cassava producing state in the south-south region of Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in Cross River States in the south-south of Nigeria. Cross River State, which is one of the 36 states in Nigeria which lies in the south-south axis of Nigeria, It is located on latitudes 4’30’ and 7’00’N and longitudes 7”50’ and 9”28’E, shares common borders with Akwa-Ibom, Abia and Ebonyi states to the west, Benue state to the north, the Republic of Cameroon to the east, and the Atlantic Ocean to the south.

The state which is tropical-humid with wet and dry seasons, having an average temperature ranging between 15-30 ^{o}C, and annual rainfall between 1300 to 3000mm, makes the soil fertile, deep and well drained with a Ph range of 4.5-6.5.

Cross River State is part of the Niger Delta region, occupying an area of about 20,156 km^2. Its headquarters is located in the ancient city of Calabar. The 2006 National Population Census puts the population of the state at an estimate about 2.8million people. The state is divided into eighteen (18) Local Government Areas (LGAs) (https://www.britannica.com/place/cross river-state-Nigeria).

2.2 Research Methodology

This study involves the use of questionnaires to obtain data from cassava processing centres. A sensitization program was conducted for enumerators drawn from the extension department of the Cross River State Agricultural Development Programme (ADP) office, who were familiar with the terrain and the cassava processors. Structured questionnaires were designed and approved by the National Centre for Agricultural Mechanization (NCAM), Ilorin, Nigeria, to obtain information on the availability, and actual use of cassava processing technologies at each unit operation of cassava processing. The Snowball technique of data collection was used to identify active cassava processing centres while the questionnaires were administered to the proprietors of the visited centres. A total of 57 questionnaires were administered to 57 respondents across 18 Local Government Areas of the State. The completed questionnaire was verified for validity and the data was collated.

2.3 Data Analysis

Data obtained from the returned questionnaires were subjected to descriptive statistical analysis involving frequency counts and percentages. Statistical Package for Social Sciences (SPSS) version 25.0. was used for computing the data captured.

3. RESULTS AND DISCUSSION

The result of the frequency count is presented in table 1. The table showed that the level of non-mechanized cassava processing was generally higher (51.27%) than the level of mechanized processing (39.76%) and the undecided (8.97%). Although the level of non-mechanized processing had the highest figure. This high figure for manual processing is an indicator of a marginal level of mechanized cassava processing in the area under study. This shows the need for agricultural mechanization stakeholders to make intensive efforts to mechanize cassava processing in the area under study. This agrees with the report of Oyelade *et al*. (2019) who reported a lower level (31.39%) of cassava processing mechanization compared to 58.19% of manual processing in Ogun State of Nigeria.

Table 1 also shows that a total of nine (9) cassava processing operations were carried out in the study area. These operations include peeling, washing, grating, chipping, dewatering, drying, garification, milling and bagging. The result further showed that cassava fermentation, Starch extraction/ Homogenization, Cassava paste moulding and cassava paste frying operations were not carried out either mechanically or manually in any of the processing centres visited in the state. Starch extraction/ Homogenization is the process of edible/ industrial starch production from cassava. Cassava starch is a popular cassava product with economic importance for producers, marketers and exporters. Cassava paste moulding and cassava paste frying are usually engaged in the production of ready-to-eat cassava balls (akara-akpu) and Lafun (fermented cassava flour), and the production of ready-to-eat fried cassava balls (akara-akpu) had the lowest level of mechanization in the area under study. The result also indicates a shortfall in the industrialization of fermented cassava products and ready-to-eat fried cassava balls.

Table 1. Results of Level of Agricultural Mechanization obtained for Cassava Processing Operations in Cross River state.

Processing operations	**Agricultural Mechanization Level**					
	MN		**MC**		**UD**	
	A	**B (%)**	**A**	**B (%)**	**A**	**B (%)**
Peeling	56	98.25	1	1.75	Nil	Nil
Washing	42	73.68	8	14.04	7	12.28
Grating	11	19.30	43	75.44	3	5.26
Chipping	31	54.39	16	28.07	10	17.54
Dewatering	9	15.79	42	73.68	6	10.53
Drying	21	36.84	28	49.12	8	14.04
Garification	41	71.93	12	21.05	4	7.02
Milling	15	26.31	36	63.16	6	10.53
Bagging	37	64.91	18	31.58	2	3.51
Total	**263 (51.27%)**	**N/A**	**204 (39.76%)**	**N/A**	**46 (8.97%)**	**N/A**

Keynote: *A = Frequency count; B = Frequency count in its percentage value; MN = Manual operation; MC = Mechanical operation; UD = Undecided; N/A = Not applicable*

Figure 1 shows that grating, dewatering and milling operations received the highest level of mechanization among all the processes reported. Washing and peeling received a considerably lower level of mechanization. This considerable low level of mechanization for peeling operations may have resulted majorly from the form of peels obtained from the cassava peeling machines. Available peeling machines turn the cassava peels (cortex) into wet mash, making it very difficult to dry and in most cases wasted. Manual peeling however results in sliced and semi-dry cassava peels which are usually used directly for animal feed or sundried and sold in an open market for further processing into animal feed.

Research shows that irregular shapes and sizes of cassava roots are responsible for the difficulties experienced in the design and fabrication of a cassava peeling machine with acceptable output efficiency. This may have resulted in the use of the manual method of peeling. According to the information gathered from the centres visited, the manual peeling is usually contracted to locals who render such services in their homes alongside washing operations, then revert to the processing centre for further processing. Since most of the locals have no mechanical cassava washing machine, most of the washing is consequently done manually.

Washing, grating, dewatering, garification and bagging are identified with unit operations involved in garri production from cassava. This relatively high level of mechanization for unit operations of garri processing can be attributed to the high demand for garri, both for local consumption and export purposes.

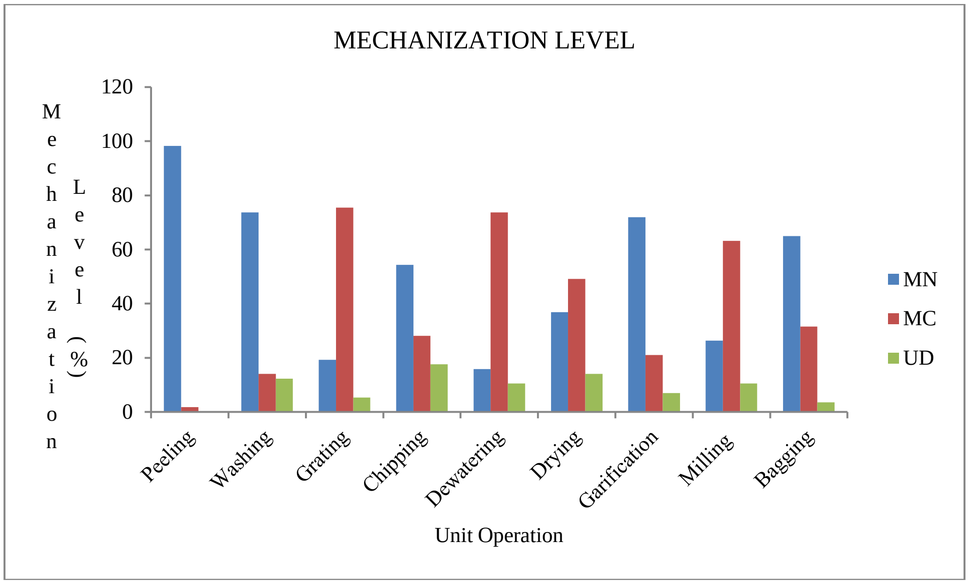

Fig 1. Representation of Agricultural Mechanization Level obtained for Cassava Root Processing in Cross-River State.

4. CONCLUSION

To ascertain Nigeria's readiness towards promoting cassava export products to foreign countries, A National Mechanization survey exercise was carried out in 2018 in Cross River State of Nigeria. The survey revealed that most cassava processing centres visited in the State adopted manual processing methods, especially for peeling, washing and garification processing of cassava tubers. It was also observed that 75.44, 73.68 and 63.16% of the cassava processing centres visited adopt mechanical processing methods for grating, dewatering and milling of cassava roots respectively. However, the sum amount of 39.76% obtained for the utilization of machines used in the nine (9) processing unit operations involved in cassava processing is obviously on the low side for a State like Cross River State.

This study revealed the present level of mechanization for cassava processing in Cross River state of Nigeria. From the study, the level of mechanization of cassava processing was lower. From the study, mechanical cassava grating, dewatering and milling operations were more involved using the machine, thus having the highest level of mechanization. It was further revealed that there is no large-scale/ limited commercial cassava starch and fried cassava balls (akara-akpu) production in the study area, Cassava paste moulding and cassava paste frying operations were not carried out in any of the processing centres in the study area. It is therefore concluded that cassava processing mechanization in Cross River state of Nigeria at the time of this study is marginally lower than manual processing. It is also concluded that large-scale cassava processing operations in the study area are carried out for selected products

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CROP COEFFICIENT, YIELD RESPONSE OF COWPEA UNDER GRAVITY DRIP IRRIGATION SYSTEM WITH MULCH

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ABSTRACT

In the northwestern region of Nigeria, Samaru, Zaria, a season experiment was conducted to estimate yield response to water stress and derive the crop coefficient of cowpea using the single crop coefficient approach with a gravity drip irrigation system and mulch. The treatments comprised three levels of water application depths (50, 75, and 100% soil moisture deficit (SMD) and three types of mulching (Black polythene mulch (BPM), Rice straw mulch (RSM), and no-mulch (NM)}. The treatments were laid out in randomized complete block design (RCBD) and replicated three times. The result obtained from the research showed that the highest seed yield of 1499.8 kg/ha was obtained when the cowpea crop was irrigated at 75% soil moisture deficit with black polyethylene mulch (I75BPM). The lowest yield of 800.4 kg/ha was obtained when irrigation was done at 50% SMD and no mulch (I50NM). The highest seasonal water use was obtained at I100NM with 242 mm and the least is at I50BPM with 120 mm. The highest irrigation water applied is at I100NM with 283.15 mm and the least is at I50BPM with 133 mm. The crop response factor (Ky) values obtained were 0.83 for NM, 0.80 for RSM, and 0.79 for BPM. The crop coefficient factor (Kc) values range from 0.28-0.71 for initial stage, 0.36-0.97 for development stage, 0.27- 0.64 for mid-season stage, 0.23-0.58 for harvesting stage. The seasonal yield response to water stress as indicated above shows that cowpea exhibits a moderately sensitive and linear response to water stress. The results suggest that cowpea is likely to give significantly higher grain yield when a nearly optimal water supply is provided with Black polythene at 75% of soil moisture deficit.

1. INTRODUCTION

The erratic rainfall patterns in Nigeria are one of the major reasons for food scarcity (Nnadi et al., 2019). Cowpea is a staple food crop and a primary source of protein and fiber for most Nigerians. Its production is critical for national food security especially during dry seasons to complement what is harvested during the rainy season.

Cowpea is adapted to dry land farming in Nigeria and is considered a drought-resistant crop. Despite its adaptation to dry land conditions, one of the major yield-limiting factors in cowpea production is water shortage. Increasing the on-farm efficiency of rainwater not only for the smallholders who grow it but would also improve food security in the whole country and bring in revenue from export sales.

In order to increase the irrigation area coverage, there is need to increase the source of irrigation water supply and/or to improve the productivity of the irrigation scheme. The latter is better under the present condition because water management has become a problem as the farmers do not know enough about cowpea's water productivity. As water scarcity demands the maximum use of every drop of water, there is a need to calculate the water productivity of crops (Pereira et al., 2002; Bessembider et al., 2005; Fereres and Soriano, 2007).

Enhancing water use efficiency in irrigated agriculture includes increasing output per unit of water, reducing water loses and prioritizing water allocation (Igbadun and Oiganji, 2012; Howel, 2001). The sustainable use of water has to consider maximizing yield per unit of water rather than maximum yield per unit of area (Feeres and Soriano, 2007).

The objectives of this paper are to determine yield responses and derive the crop coefficient of cowpea under deficit irrigation with mulch materials under drip irrigation system.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

2.1.1 Location

Field experiment was conducted between 16th February to 2nd May, 2015/2016 dry season at the Department of Agricultural and Bio-resources Engineering Irrigation Experimental Field, Ahmadu Bello University, Zaria. It lies on latitude 11^0 11 'N, longitude 7°38'E, and altitude 686 m above mean sea level in the northern guinea savannah ecological zone of Nigeria with a semi-arid climate. The Mean annual rainfall of the study area is reported to be 1015.9 mm with an onset and cessation of rainfall as 21st May and 7th October respectively. The mean maximum air temperature is 29.7°C while the mean minimum air temperature is 13.3°C.

2.2 Soil Data Analysis

The physical characteristics of the experimental soils were determined at depths of 0-15 cm, 15- 30 cm and 30 – 45 cm, 45 – 60 cm, 60 – 75 cm using (hydrometer and pressure plates) the hydrometer method is for determination of soil particle size distribution and water retention with pressure plate apparatus (Galvak et al., 2005). The soil physical characteristics of the experimental plot showed the top soil to be loam with 1.82 g/cm^3 bulk density and underlined by clay loam (15-45 cm) with an average bulk density of 1.54 g/cm^3 as obtained from Soil Science Departmental Laboratory at Ahmadu Bello University, Zaria.

2.3 Treatment and Experimental Design

The experiment consisted of two factors namely: Irrigation at three (3) levels (50%,75% and 100% of Soil Moisture Deficit (SMD)) and three types of mulching materials (No mulch, rice straw and black polythene mulch) giving a total of a 9 treatments laid in Randomized Complete Block Design (RCBD) with three replications.

2.4 Test Crop

Sampea 8: The variety was obtained from seed processing Unit of Institute for Agricultural Research, Samaru, Zaria. It has a semi-erect growth habit, early maturing (60 – 65 days), medium white seeds with yield potential of 1200 kgha^{-1} it has some level of resistance to insects and diseases.

2.5 Cultural Practices

The experimental fields were cleared, harrowed and made into ridges to create a favourable condition for seed establishment, and a distance of 0.75 m between rigdes and 1m between blocks. The field was marked into three (3) plots and nine (9) laterals per replication, with a total of 27 laterals.

The seeds were sown manually at three seeds per hole with an inter-row and intra-row spacing of 75cm and 30cm respectively at the rate 25 $kgha^{-1}$ (reason for change in conventional spacing is due to the emitter design spacing). After germination seedlings were thinned to two plants per stand 10 days after emergence. Fertilizer was applied using 100kg of compound fertilizer (N.P.K 20-40-20) per hectare and 30 kg SSP (Dugje *et al.*, 2009).The fertilizer was applied during planting of the seeds. Pre-emergency herbicide (gramazone) was used to kill the weeds on the day of planting. Thereafter weeding in the plots was done manually with hoe which was carried out two times two weeks and four weeks respectively after planting.

Prior to planting, soil moisture content at depths up to 20 mm were determined using the gravimetric method and one irrigation applied to raise the moisture content of the soil one day before planting to field capacity level., Full irrigation to restore soil moisture content to field capacity based on effective rooting depth of 5 cm, was given to all treatment plots for 10 days. The uniform application of water was done to ensure the crop is properly established before imposing the treatments.

The mulch materials were placed two weeks after planting. The polyethylene material (black) were cut to size and placed over the ridge. Holes were created in accordance with the plant spacing and the cowpea seedlings were passed through the holes carefully. The thickness of the polyethylene measured with a micrometre screw gauge was about 2 mm. The average weight of rice straw mulch spread in each of the plot with such treatment was 60 kg/ha of rice straw mulch was applied uniformly on each plot according to treatment description.

There was incidence of Aphis*(craccivora)* at about 4 weeks after planting, which was managed with the application of "sharp shooter*"(projenofos 40% + cypermethrin 4% E.C)* at 0.81itre/ha using 40 ml in 15 liters' knapsack sprayer as recommended by Avav and Ayuba (2006). Insect pests were controlled at 2 weeks after sowing, pre-flowering, flowering and podding stages. The crops were sprayed using Lara Force, with an active ingredient Lambda-cyhalothrin 25% EC. Hundred mils of insecticides was mixed with 16 liters of water and sprayed while fungal diseases were controlled using Benomyl as benated (50WP). Rabbit is another pest that affected the crop at the pod formation stage; this was properly managed traditionally by the use of local traps. The harvesting of the dried pods started 5 weeks after sowing. Picking was carried out three times at an interval of two weeks, this was carried out by hand–picking when the pods were fully matured and dried. All the net plots were harvested separately. Harvested pods were sun dried before threshing and the threshed seeds were further dried in the sun before weighing. The grain weight per each net plot was weighed and converted to grain yield in kilogram per hectare (kg/ha).

2.6 Soil Moisture Determination

Soil moisture content was monitored throughout the crop growing seasons with ML3 Theta Probe (Delta –T devices, London). The Theta Probe measures moisture content in-situ and expresses the volumetric soil moisture regime. Soil moisture measurement through the soil profile was done a day after an irrigation and before next irrigation at incremental depth of 0-15, 15-30, 45-60, 60-75 cm. 5 nos of 7.2 cm diameter PVC pipes were installed to the depths mentioned above in each plot. The pipe provides access for inserting the theta probe into the soil. Soil moisture measurement was made by inserting the sensing head of the theta probe into the soil through the access pipes to the various depths required below the soil surface.

2.7 Water Source

Surface runoff harvested from departmental drainage channels and stored in a 50 m^3capacity underground sump, 6 m deep, was the main source of the irrigation water. The sump water was recharged daily from the university water supply. A 2 horse power petrol engine pump was used to lift water from the underground tank to the elevated tanks, 2 m above ground which was placed on a concrete stand. When water has been pumped to the full capacity in tank A, the valve at the junction of pipe that supply water to tank A is closed. Valve at the junction that supply water to tank B is then opened until tank B is filled to capacity. Tank B supplies water to plots 2 and 3.

2.8 Drip System Components

Water from the elevated tanks release into a supply line 20 mm diameter, 5 m long made from Low Density Polyethylene Pipe (LDPEP). A ball valve and a primary filter are fixed on the line and it terminated at a 20 mm, 19 m long mainline of the same material. Four sub- mainlines each 180cm long, and 20 mm diameter was connected to the mainline. There were 27 laterals altogether installed. The hydraulic characteristics of the system installed that were evaluated included: emitter flow rate, emitter flow rate variation, uniformity coefficient and emission uniformity.

Table 1. Experimental Treatments and their Description

Treatment No	Treatment combinations	Description of treatment combinations
1.	I_{100}NM	Water application depth of 100% of SMD at, no mulch.
2.	I_{75}NM	Water application depth of 75% of SMD, no mulch
3.	I_{50}NM	Water application depth of 50% of SMD, no mulch
4.	I_{100}RSM	Water application depth of 100% of SMD, with rice straw mulch.
5.	I_{75}RSM	Water application depth of 75% of SMD with rice straw mulch.
6.	I_{50}RSM	Water application depth of 50% of SMD with rice straw mulch.
7.	I_{100}BPM	Water application depth of 100% of SMD with black polythene mulch.
8.	I_{75}BPM	Water application depth of 75% of SMD with black polythene mulch.
9.	I_{50}BPM	Water application depth of 50% of SMD with black polythene mulch.

Plates 1.1 and 1.2 are the layout of the laterals before planting operation.

1.1 Field Layout with Drip Laterals Component of the System

1.2 Hydraulic Evaluation of Drip System Layout

2.9 Data Collection Procedures

Measurement of emitter discharges were carried out from nine drip tubes randomly selected from each of the three junctions. In each drip tube five emitters were randomly selected from each quarter of the lateral length, giving a total of twenty emitters per drip tube. A total of one hundred and eighty emitters were tested in this research. Water cans were placed below the tubes to collect water dripping from the designated emitters over a given time. The water collected in each can was measured using a graduated cylinder; each emitter discharge measurement was replicated three times. The water temperature at the time of measurement was between 30°C and 38.5°C. The pressure heads at the upstream and downstream ends of the drips were measured using Pilot tube in the designated laterals.

The operating pressure was monitored using the Pitot tube to ensure that the pressure remained constant during each set of measurements. Emitter discharge was measured over a range of pressures because the junctions to which the laterals/drip tubes were connected were at different elevations along the sub-main in the experimental field.

2.10 Computation of emitter flow variation (Q_{var})

This was obtained as (Solomon, 2000):

$$Q_{var}(\%) = 100\left(\frac{qmax - qmin}{qmax}\right) \quad (1)$$

where,

Q_{var} =emitter flow variation

q_{max} = maximum emitter flow along the lateral line (1/hr)

q_{mm} = minimum emitter flow along the lateral line (1/hr)

2.11 Computation of emission uniformity (EU)

$$EU = 100(q_{iq}q/q) \quad (2)$$

where,

$q_{iq}q$= Average rate at low quarter (25%) of emitter discharge observations (1/hr.)

q = Average discharge rate of all observations (1/hr)

2.12 Wetting Diameter

One hour after irrigation, the diameter of the soil wetted by each emitter was measured using a ruler. It was found to be 17cm in diameter.

2.13 Computation of Coefficient of Variation

$$CV = \frac{Sq}{Qave} X\ 100 \quad (3)$$

where,

CV=Coefficient of Variation

Sq = standard deviation of discharge

q_{ave} = average discharge

2.14 Computation of Total Available Water

Michael (1978) gave the formula for determining Total Available Water (TAW) as:

$$TAW = \left(\frac{FC - PWP}{100}\right).Dz \qquad (4)$$

where,

TAW = Total available water (mm)
Dz = depth of root zone (mm)
FC= field capacity (% weight)
PWP = Permanent wilting point (%weight)

According to Hune (2009), in drip irrigation, runoff, deep percolation and ground water contribution are all negligible because water is applied to the soil at and within the root zone at an application rate less than the soil infiltration rate. Therefore, the actual crop evapotranspiration between irrigations will be determined on the basis of change in mean value of soil water storage at 15cm incremental soil depth, from the day of irrigation, when the soil will be raised to the upper volumetric limit at which irrigation levels will be based to a day before the next irrigation. Now the actual crop evapotranspiration will be calculated as (Micheal, 1978):

$$ETa = \sum_{i=1}^{n} \frac{(MCa - MCb)}{t} Dz \qquad (5)$$

where,

Eta = Actual crop evapotranspiration
M_{Cb} = Moisture content before irrigation (m^3/m^3)
M_{Ca} = Moisture content after irrigation (m^3/m^3)
t = Number of days since last irrigation to the day of sampling
N = number of soil layers.

2.15 Computation of Yield Response Factor to Water Deficit

This was obtained as Doorenbos and Kassam (1979):

$$1 - \frac{Ya}{Ym} = Ky\left(1 - \frac{ETa}{ETm}\right) \qquad (6)$$

where,

Ya and Ym are the actual and maximum yield in kg/ha, respectively.

ETa and ETm are the actual and maximum evapotranspiration in mm, Ky is the yield response factor representing the effect of a reduction in evapotranspiration on yield reduction.

2.16 Statistical Analysis

The data collected were subjected to analysis of variance using SAS (9.0). Treatment mean were compare using LSD at 5% level of probability.

3. RESULTS AND DISCUSSION

3.1 Irrigation Water Applied and Seasonal Water Use

Table 2 shows the variation of water application depth along the growing season for the tested rates of water deficits. The table illustrates that, water application depth, for all treatments, took the same trend along the growing season, but with lower values according to the percent of water deficit. The figures also show that, water application depth for each treatment no matter the types of mulch material used had significantly affected availability of moisture to the crop. Irrigating at 100% of soil moisture depletion (SMD) with mulch (BPM) gives lower moisture depletion from the soil which is in line with Othman (2007) who reported on soil moisture conservation by mulch**.**

Table 2. Irrigation Water Applied (mm) for Cowpea during 2016 dry Season

Treatment	I_{100} RSM	I_{100} BPM	I_{100} NM	I_{75} RSM	I_{75} BPM	I_{75} NM	I_{50} RSM	I_{50} BPM	I_{50} NM
17/2/2016	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
21/2/2016	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
25/2/2016	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
29/2/2016	9.7	6.8	16.0	5.2	5.0	6.2	3.2	4.5	10.0
03/3/2016	9.8	7.0	16.1	5.9	6.3	6.9	3.4	4.6	10.9
07/3/2016	10.9	9.2	17.3	5.2	9.0	10.2	3.6	3.8	5.2
11/3/2016	10.9	9.8	17.3	6.0	8.9	9.0	4.2	3.4	5.4
16/3/2016	14.6	9.0	21.0	4.2	8.0	11.1	6.2	5.1	6.7
28/3/2016	14.9	9.3	22.5	4.5	8.2	11.2	6.8	6.0	6.8
31/3/2016	16.1	12.0	18.0	9.1	9.0	12.4	7.5	7.2	7.1
04/4/2016	16.3	13.9	18.2	10.0	6.3	12.3	7.0	7.6	6.4
08/4/2016	15.2	14.1	17.1	10.2	7.2	10.5	8.1	5.3	10.0
12/4/2016	9.5	15.0	17.2	9.7	5.2	11.0	7.0	5.4	9.0
16/4/2016	9.2	9.0	17.2	5.7	4.7	10.9	3.8	4.8	6.8
20/4/2016	7.2	9.9	17.6	5.2	4.5	10.9	3.6	4.9	7.2
24/4/2016	7.0	5.1	14.0	5.3	4.6	6.0	3.4	3.2	9.9
28/4/2016	6.5	6.1	14.5	7.7	4.3	6.3	3.2	3.4	6.1
02/5/2016	5.0	5.1	6.2	4.3	2.9	3.9	2.6	2.8	3.1
Total	**223.95**	**202.3**	**311.15**	**159.2**	**155.1**	**199.8**	**134.6**	**133**	**168.6**

Table 3. **Crop Water Use for Cowpea during 2015/2016 Dry Season**

Treatment	I_{100} RSM	I_{100} BPM	I_{100} NM	I_{75} RSM	I_{75} BPM	I_{75} NM	I_{50} RSM	I_{50} BPM	I_{50} NM
21/2/2016	5.0	6.0	9.0	6.0	5.0	5.0	5.0	5.0	6.0
25/2/2016	6.0	7.0	8.0	5.0	7.0	7.0	6.0	4.0	7.0
29/2/2016	6.0	8.0	16.0	6.0	8.0	7.0	7.0	5.0	6.0
03/3/2016	9.0	8.0	16.0	6.0	12.0	6.0	6.0	7.0	7.0
07/3/2016	10.0	9.0	17.0	6.0	12.0	7.0	7.0	6.0	7.0
11/3/2016	11.0	9.0	18.0	7.0	11.0	9.0	8.0	6.0	10.0
16/3/2016	11.0	13.0	20.0	8.0	12.0	10.0	13.0	11.0	10.0
28/3/2016	11.5	14.0	22.0	8.0	11.0	13.0	19.0	15.0	17.0
31/3/2016	11.8	14.0	20.0	7.0	12.0	14.0	15.0	15.0	15.0
04/4/2016	16.0	15.0	14.0	19.0	8.0	15.0	7.0	14.0	20.0
08/4/2016	16.2	10.0	20.0	10.0	9.0	15.0	8.0	14.0	16.0
12/4/2016	15.0	9.0	19.0	14.0	7.0	16.0	7.0	13.0	16.0
16/4/2016	15.0	5.0	9.0	15.0	8.0	17.0	6.0	8.0	15.0
20/4/2016	10.0	6.0	9.0	7.0	6.0	19.0	4.0	7.0	12.0
24/4/2016	9.0	6.0	7.0	5.0	6.0	10.0	5.0	5.0	11.0
28/4/2016	7.0	5.0	6.0	7.0	6.0	8.0	4.0	4.0	10.0
02/5/2016	5.0	5.0	5.0	5.0	4.5	8.0	5.0	5.0	5.0
Total	**179.5**	**155**	**242**	**148**	**149.5**	**152**	**117**	**120**	**135**

It can be noticed that the irrigation water applied and the seasonal water use decreased with an increase in deficit irrigation. The pattern of decrease in water use as a result of deficit irrigation was expected since deficit irrigation reduces the amount of water available in the soil for the plant to use. The highest irrigation water applied under irrigation treatment was at 100% SMD with 311.15 mm followed by 75%SMD with 199.8 mm then 50% ETo with 168.6 mm. However, the seasonal water use was significantly higher at 100% soil moisture depletion with 242 mm compared to the seasonal water use at 75% SMD and 50%SMD. In general, irrigation water applied and seasonal water use was found to decrease with a decrease in % of soil moisture depletion from 100% to 50%. However, with the use of different mulch materials, both the irrigation water applied and the seasonal water use recorded have high values at NM with 311.15 mm and 242.55 mm, while RSM and BPM were found to be similar. Mulching with rice straw and black polyethylene recorded significantly lower values of irrigation water applied and seasonal water use for cowpea compared to the no mulch treatment. This is expected as mulching helps to conserve moisture for crop use.

3.2 Crop Coefficient

The trend of crop factors for cowpea during the different phonological stages at full irrigation treatment is presented in Table 4. The Kc value shows a curve that peaks during the flowering/podding (midseason) of the crop. The Kc values for emergence (initial stage), Vegetative, Mid-season (flowering and pod formation), and senescence (late season) were 0.37, 0.9, 0.96, and 0.45 for no-mulch condition. Declining Kc values during the maturity stage might be due to reduced sensitivity of the stomata as leaves begin to senescence (Fraust, 1989). The Kc values obtained show that the highest water requirement occurs at the flowering and pod formation (midseason) stage.

In more elaborate form, the Kc values for RSM ranged from 0.3 - 0.8 for initial stage, 0.79 - 0.94 for development stage, 0.80 - 0.94 for mid-season and 0.43 - 0.91 for late season. For BPM the value ranges from 0.28 - 0.58 for initial stage, 0.82-0.94 for development stage, 0.88 - 0.96 for mid-season and 0.38 - 0.76 for late season. For NM the value ranges from 0.37 -1.2 for initial stage, 0.9 -1.09 for development stage, 0.96 - 1.09 for mid-season and 0.45 – 1.02 for late season. The Food and Agricultural Organization (FAO 1977) reported an estimate of Kc for different development stages of cowpea as 0.4 for the initial stage, 0.4, 1 and 1.5.

For the development stage, 1.05 for the mid-stage and 0.90 late seasons stage which is in the raofwiofhe Kc values estimated in this research. Also, the Kc value obtained is similar to the value obtained by Aboamera (2010) as 0.696, 0.651,0.673, and 0.60 for the initial, development, mid-season, and harvesting stage respectively with the full irrigation (100% of SMD). The reason in the Kc values at the mid-season stage is lower could be attributed to the low-temperature range, inherent variability in crop characteristics at the growth stage, and the fertilizer application that was not done as when due.

Table 4. ETo, ETa and Kc for the Growth Stages for Cowpea In the 2015/2016 Season

Treatment label	Initial stage			Development stage			Flowering/podding stage			Harvesting stage		
	ETo	ETa	Kc	ETo	ETa	Kc	ETo	ETa	Kc	ETo	ETa	Kc
I_{100}RSM	5.6	2.3	0.4	5.5	2.3	0.41	7.0	4.1	0.59	7.0	2.8	0.4
I_{100}BPM	5.6	2.2	0.4	5.5	3.3	0.61	7.0	2.6	0.37	7.0	2.0	0.3
I_{100}NM	5.6	4.0	0.7	5.5	5.3	0.97	7.0	4.3	0.62	7.0	2.6	0.4
I_{75}RSM	5.6	1.7	0.3	5.5	2.0	0.36	7.0	3.9	0.55	7.0	2.2	0.3
I_{75}BPM	5.6	2.6	0.5	5.5	3.1	0.56	7.0	2.1	0.31	7.0	2.1	0.3
I_{75}NM	5.6	1.9	0.4	5.5	3.7	0.68	7.0	4.2	0.60	7.0	4.1	0.5
I_{50}RSM	5.6	1.9	0.3	5.5	3.67	0.67	7.0	1.9	0.27	7.0	1.6	0.2
I_{50}BPM	5.6	1.6	0.3	5.5	3.13	0.57	7.0	3.3	0.47	7.0	2.3	0.3
I_{50}NM	5.6	2.0	0.4	5.5	3.90	0.70	7.0	4.5	0.64	7.0	3. 5	0.5

Table 5. Cumulative Evapotranspiration during the Growth Stages

Treatment label	Cumulative evapotranspiration (ETa) for growth stages (mm)				Seasonal total (mm)
	Initial (0-21 DAP)	Development (22-37 DAP)	Flowering/Podding (38-53 DAP)	Harvesting (54-65 DAP)	60-65 DAP
I_{100}RSM	34	48	62	31	175^{bc}
I_{100}BPM	40	47	42	20	149^{c}
I_{100}NM	63	79	70	23	235^{a}
I_{75}RSM	36	30	53	22	141^{de}
I_{75}BPM	34	48	44	18	144^{d}
I_{75}NM	40	51	53	43	187^{b}
I_{50}RSM	29	55	30	18	124^{fg}
I_{50}BPM	21	37	39	23	120^{fg}
I_{50}NM	27	41	45	22	135^{f}

Note**: Means followed by the same letter(s), in a column of any treatment group are not significantly different at p < 5 %. Where I_{100}, I_{75}, I_{50} are 100, 75, and 50% of soil moisture deficit respectively. RSM = rice straw mulch, BPM = Black polythene mulch, NM = No mulch.** Statistically test the significant difference between the values of the seasonal total for all the treatments.

3.3 The crop yield response factor

Figures 2-4 show the yield response factors (Ky) for NM, RSM, and BPM treatments, respectively obtained by plotting the data of the relative yields and relative seasonal crop water use of the treatment. The crop response Ky values were obtained as 0.83, 0.83 and 0.79.for the NM, RSM and BPM, respectively.

The coefficient of determination (r^2) for black polythene relationship was good (>0.75) while for that of rice straw and no-mulch were average at 0.57 and 0.58, respectively. According to Doorenbos and Kassam (1979), Ky <1.0 indicates that the decrease in yield is proportionally less with increase in water deficit, while yield decrease is proportionally greater when y>1.0.

The results of this study show that with mulch, the decrease in yield of the cowpea crop were proportionally less with increase in moisture deficit. It is however, noticed that the Ky values of the no-mulch treatment was higher than the mulched treatment by about 13.8 to 17.73%, which implies that the proportional decrease in yield under the no mulch treatment was much higher than the mulched treatment this may be due to effect of mulch material used which alleviated the effect of water stress.

Generally, higher Ky values indicate that the crop will have a greater yield loss when the crop water requirements are not met. This result indicated less impact of soil-water stress treatment on the cowpea yield.

The yield response factor (Ky) for cowpea in Samaru was found to be 0.783 for the growing season in this study.

Table 6. Computed Yield Response Factor

Treatment	Ya	Ym	ETa	ETm	Ya/Ym	ETa/ETm	1- (Ya/Ym)	1- (ETa/ETm)
I_{100} NM	1425.5	1425.5	242	242.33	1	1	0	0
I_{100} RSM	1428.6	1428.6	179.5	179.53	1	1	0	0
I_{100} BPM	1520.6	1520.6	155.5	155.54	1	1	0	0
I_{75}NM	1362		152		0.851	0.628	0.149	0.372
I_{75}RSM	1397.8		148		0.814	0.955	0.186	0.045
I_{75}BPM	1499.8		149		0.960	0.833	0.040	0.167
I_{50}NM	800.1		135		0.705	0.478	0.294	0.522
I_{50}RSM	978.4		117		0.774	0.755	0.226	0.245
I_{50} BPM	1103.3		120		0.733	0.669	0.267	0.331

Ym = 1425.5 Kg/ha, 1428.6 Kg/ha, 1520.6 Kg/ha corresponding to NM, RSM and BPM respectively at full irrigation; ETm = 242.33, 179.53, 155.54 for NM, RSM and BPM respectively.

3.4 Seed Yield -Seasonal Water Applied Relationship for the Cowpea Crop

Irrigation water applied throughout the irrigation season shows a linear response to yield however, yield began to decline at 200 mm depth of application this indicate additional water applied will not only unprofitable but will cause harm to the crop environment.

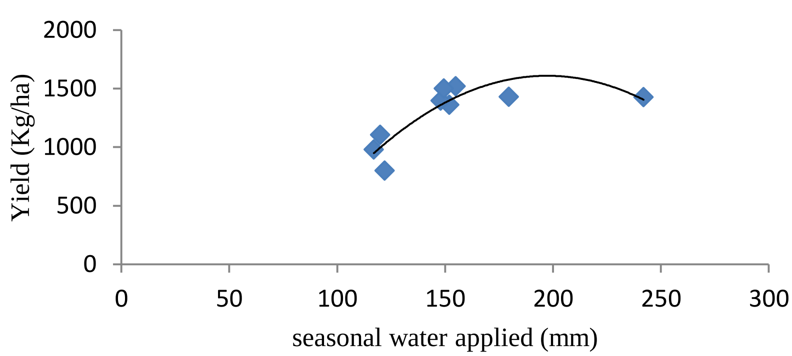

Fig 1. Seed yield -seasonal water application relationship

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