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CROP COEFFICIENT DETERMINATION OF A SIX-MONTH VARIETY CASSAVA

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ABSTRACT

The amount of water lost by plants and their environment through transpiration and evaporation affects the growth, development and yield of a crop. For good irrigation design and scheduling, it is necessary to know the amount of water consumed by the crop and its environment in order to satisfy the water requirements. This paper reports preliminary investigations of the crop coefficient, (K_c) and water requirements of a 6-month variety cassava known as *Atra*. Known locally as *bosome nsia* and using a locally constructed micro-lysimeter for an experimental period of 180 days (17 November 2000 to 16 May 2001) in Kumasi (06° 43' N; 01° 36' W), Ghana, the K_c values estimated were: establishment stage (0.398); development stage (1.010); mid-season stage (1.558); late season stage (1.018). The average value for the entire growth period was 1.102. Crop water requirements were also estimated at 1212 mm. A graph of plant height, H (mm) against cumulative water use, CWU (mm) gave a power relation $H = 60.33\ CWU^{0.39}$, with r^2 of 0.9913. From the relationship obtained, if the maximum plant height and relative growth for the given period is known, the consumptive use and therefore the crop-coefficient for the cassava crop can be predicted for the given period.

KEYWORDS

Crop coefficient, Cassava

1. INTRODUCTION

Cassava, *Manihot esculenta*, also called manioc, mandioca, yucca, etc is a perennial tuberous root crop of the family Euphorbiaceae (Kochlar, 1981). It is believed to be of South American origin (i.e. Brazil, Mexico and Venezuela regions) and was taken to West Africa by the Portuguese in the sixteenth century. It is now grown on nearly 10 million ha of land mostly in Brazil, Indonesia, Congo, Nigeria, Zaire, Uganda etc. World production in 1974 was estimated to be 104 million metric tones (Kochlar, 1981). Cassava is a shrubby, short-lived perennial with an erect stem marked by prominent knobby leaf scars. Heights of fully-grown plants differ with cultivars and ranges between 1 – 3m. Leaves are spirally arranged with long petioles subtended by small deciduous stipules. They are usually dark green but red, yellow, and various shades of purple pigmentation occur in the foliage. Two main cultivars are recognized based on the hydrocyanide (HCN) content of the tubers. These are (Purseglove, 1984) the sweet type with low HCN content and the bitter type with a higher HCN content. Cassava is best grown on a friable, fertile and well drained sandy loam soils but can be grown economically on poor exhausted land with little care (Kochlar, 1981). Cassava can thrive in areas with annual rainfall values of 500-5000mm and full sun and is susceptible to cold weather and frost. Means of propagation is by use of stem cuttings for agricultural purposes and by seeds for breeding and selection purposes. The crop is planted either as pure stands or intercropped with corn, legumes, yam and some vegetables. Some varieties mature in as little as six months while others may continue to increase in size for up to 4 years on the field. If kept for too long on the field, the tubers become rather woody and commercially not desirable. In Ghana, because the crop grows practically anywhere and under any condition, however, there is hardly any information on field water management of the crop as related to such parameters as crop coefficient and crop water requirements. Currently, cassava has moved from being a staple to being an export crop,

meaning that the production methods must change and this will require, in part, sufficient knowledge on its water use.

Consumptive use or crop evapotranspiration (ET_c) is commonly used to describe the total process of water vapour transfer into the atmosphere from vegetated land surfaces (Teare and Peat (1983). It is made up of two terms: (i) evaporation, which is the physical process for the change of liquid water to gaseous water vapour and could occur on open water or wet surfaces; (ii) transpiration, which is the evaporation of water that has been absorbed through plant roots, transported through the plant, controlled by the stomatal aperture and then removed from leaf surfaces (Teare and Peat (1983). Other factors being equal, the stage of growth of a crop has a considerable influence on its consumptive use rate. This is said to be true particularly for annual crops, which generally have 3 rather distinct stages of growth namely, (i) emergence and development of vegetative cover, during which time consumptive use rate increases rapidly from a low value and approaches its maximum; (ii) the period of maximum vegetative cover during which time the consumptive rate may be maximum if abundant soil moisture is available and (iii) crop maturation stage, when for most crops, the consumptive use rate begins to decline.

Crop evapotranspiration (ET_c), as it is sometimes called, is a function of the crop coefficient (K_c) and the potential ability of the crop and its environment to give up water. Potential evapotranspiration (ET_o) is defined as the evapotranspiration from an actively growing short green vegetation completely shading the ground and never short of moisture availability (Michael, 1978) and it depends on the climatic factors governing the ET_c process. For good irrigation design and scheduling, information on weekly ET_o as well as a reasonable estimate of the optimum irrigation intervals is necessary (Shalhevet et al, 1981) since success of irrigation largely depends on adequacy and the dependability of its water supply (Doorenbos and Pruitt, 1975). Various methods have been used to determine the amount of water consumed by agricultural crops and natural vegetation. However there are numerous problems encountered regardless of the method chosen (Hansen, Israelson and Stringham, 1975). The accurate assessment of ET_c is a vital part of proper water management schemes. The problems arise from the complex set of factors influencing ET rate. Where methods involve direct measurements of water loss, replication of measurement problems lead to certain factors being ignored or inaccuracies in their determination. In the tropics, sparse meteorological networks, manpower and financial limitations increase the problem (Jackson, 1982).

Methods for estimating ET could be by direct measurement, indirect methods from climatic observation and by estimation from evaporation data. This paper reports a preliminary study of the determination of crop coefficient of a 6-month variety cassava using a locally constructed micro-lysimeter.

2. MATERIALS AND METHODS

The set-up for the experiment was located near the weather station of the Department of Agricultural Engineering of the Kwame Nkrumah University of Science and Technology, Kumasi (06° 43' N; 01° 36' W). Average day length of the location is about 12hours. Mean maximum and minimum temperatures are 32°C and 22°C respectively; and day and night relative humidity are 60% and 95% respectively. Annual rainfall averages at 1420 mm. The average climatic conditions for the experimental period are summarized in Table 1. A steel pipe measuring 254 mm in diameter was used to construct a micro-lysimeter, with detailed specification as shown below in Figure 1 (Agbakpe, 2001).

The test crop used was the *Atra* variety of cassava locally called "*bosome nsia*". It took 16 days for the stem cutting to sprout and the growth period is 180 days under optimum conditions. A well-drained, unsterilised loamy soil of the forest ochrosol group, locally known as *Asawasi* series was used for the experiment. The soils were then compacted to a bulk density of 1300 kg/m^3. The open tank was filled with water as specified in Figure 1 above. Depth of water in the tank was measured daily at about 09.00 hours and the depth changes noted as the amount of water used by the crop (ET_c). In the event of rainfall, the reading was discarded in order to allow the system to readjust to equilibrium. ET_o was estimated from pot evaporation measurements developed by Agodzo, Gowing and Adey (1996) and the

K_c values estimated as ET_c/ET_o. Planting was done, after the soil was drained, with a single stem of height about 25 cm in the tank containing the soil. Ten grams of NPK fertilizer was applied four weeks after sprouting and was repeated twice in a six-week interval. The ring mode of application was adopted. The crop was harvested after the growth period of six months (180days). It yielded two tubers, which were weighed, and the total weight of yield noted.

Table1. Climatic Data of Site for the Experimental Period, Nov. 2000 – May 2001

Month	Nov	Dec	Jan	Feb	March	April	May
Mean Rainfall (mm)	52.40	*TR	*TR	21.50	145.9	142.8	80.00
Relative Humidity (%)	78.25	73.25	68.00	59.50	74.00	78.00	78.00
Mean Sunshine Hours	7.00	5.80	6.90	7.30	7.00	7.10	6.70
Average Wind Speed (km/day)	62.10	57.40	59.20	69.60	72.00	68.40	66.70
Mean Temperature (^{0}C)	26.90	26.30	27.60	28.80	28.30	27.30	27.30

*TR = Traces of Rain (Less than 0.10 mm of Rainfall)

Source: Department of Agric Engineering Meteorological Station, KNUST

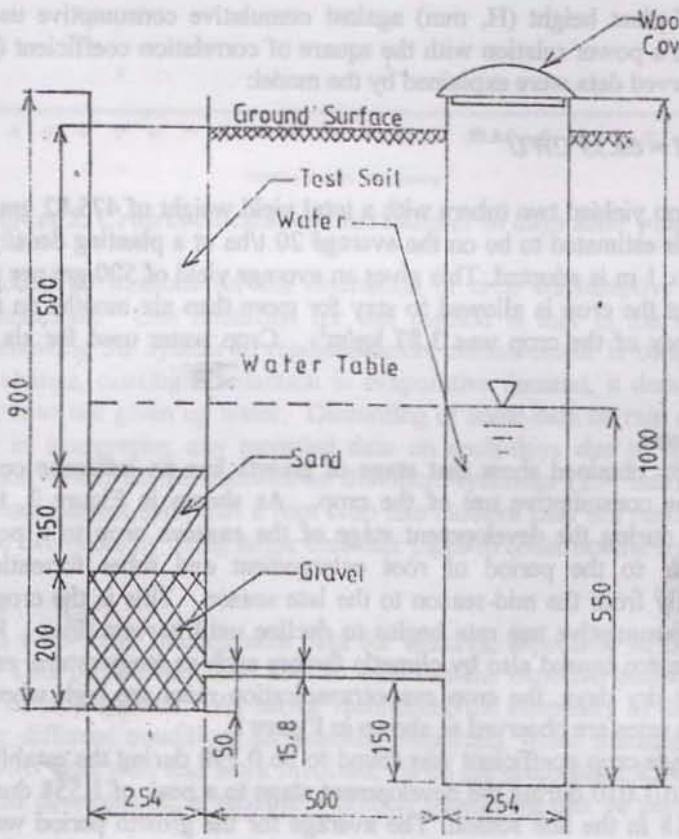

Figure 1. Experimental set-up All Dimensions in mm

The sequence of activities from the start of the season to the end can be summarized as follows: Planting of stem cutting (17-11-00), Sprouting of cutting (03-12-00), First application of fertilizer (31-12-00), Second application of fertilizer (11-02-01), Third application of fertilizer (25-03-01), Harvesting (29-05-01).

3. RESULTS AND DISCUSSION

3.1 Results

Mean monthly rainfall values for the growth period are 52.4 mm for November, no significant rainfall values for December and January; 21.5, 145.9, 142.8 and 80 mm for February, March, April and May respectively as shown in Table 1. Time series plot of K_c values is shown in Figure 2 and the summary of ET_c, ET_o and K_c values for the growth stages of the crop are shown in Table 2.

Table 2. Growth stages of cassava and their respective ET_c, ET_o and K_c

Stage	ET_c (mm/day)	ET_o (mm/day)	K_c
Establishment (1 – 35 days)	2.545	6.348	0.398
Development (36 – 85 days)	6.633	6.569	1.010
Mid-Season (86 – 165 days)	9.290	5.559	1.558
Late-Season (166 – 180 days)	4.500	4.327	1.018
Growth period (1- 180 days)	6.732	5.890	1.102

When a graph of plant height (H, mm) against cumulative consumptive use (CWU, mm) was plotted (Figure 3), it gave a power relation with the square of correlation coefficient (r^2) of 0.9956, implying that nearly all the observed data were explained by the model:

$$H = 60.33\ CWU^{0.39} \qquad (1)$$

At harvest, the crop yielded two tubers with a total yield weight of 475.82 gm. On the field, the optimum yield per hectare is estimated to be on the average 20 t/ha at a planting density of 40,000 plants/ha, when a spacing of 1 m x 1 m is adopted. This gives an average yield of 500 gm per plant under such a condition (Asare, 1999), but the crop is allowed to stay for more than six months on the field in most cases. The water use efficiency of the crop was 3.87 kg/m^3. Crop water used for six months amounted to about 1212 mm.

3.2 Discussion

The results obtained show that stage of growth has an influence on the evapotranspiration and therefore upon the consumptive use of the crop. As shown in Figure 2, the rate of consumptive use increases rapidly during the development stage of the cassava crop to a peak at the mid-season stage, which corresponds to the period of root enlargement and tuber formation. Consumptive rate then decreases gradually from the mid-season to the late season. This is the crop maturation stage when for most crops the consumptive use rate begins to decline until harvest time. Large variations in the daily evapotranspiration are caused also by climatic factors such as temperature, relative humidity and rainfall. Especially on hot dry days, the crop evapotranspiration rates are high whereas on rainy, wet and cool days, decreases in rates are observed as shown in Figure 2.

The average crop coefficient was found to be 0.390 during the establishment stage of the cassava crop. This rose to 1.010 during the development stage to a peak of 1.558 during the mid-season and then decreased to 1.018 in the late season. The average for the growth period was found to be 1.102. Crop coefficient values for cassava were difficult to find in literature and hence it was not possible to make any comparisons. However, the trend follows that of a typical crop. These values of K_c are very important in achieving efficient and reliable irrigation scheduling for cassava.

The simplicity of the method suggests that it can be replicated under different conditions to establish important water management parameters for cassava. In Ghana, for example, when considering crops for irrigation, cassava may not be considered a priority but indications are that the commercial value of the crop is increasing and therefore requires that traditional production methods be reviewed to cope with the increase in demand.

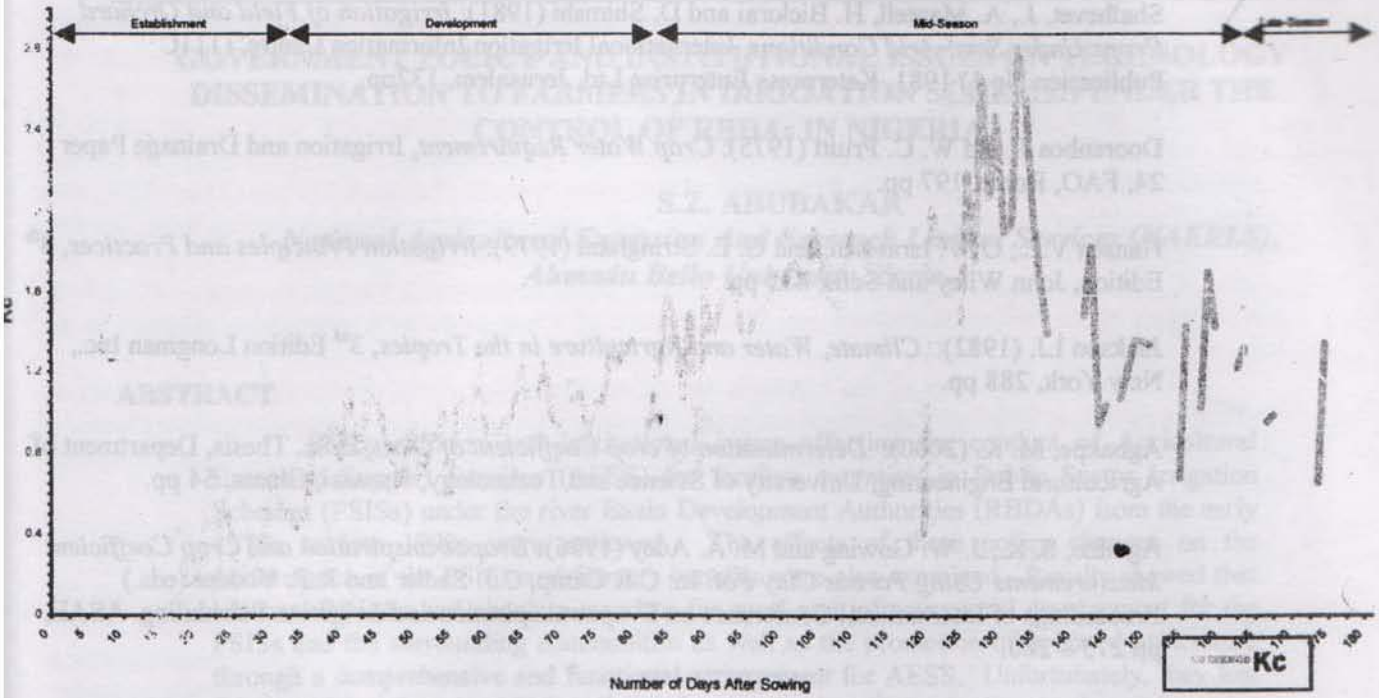

Figure 2. Crop coefficient against number of days after planting

As earlier mentioned all methods for the estimation of crop consumptive use and hence crop coefficient have their limitations. One limitation for this method is that in the event of rainfall, the readings are discarded, allowing the system to readjust before measurement is continued. Even though weather conditions may change, causing a reduction in evaporative demand, it does not suggest that the crop and its environment have not given up water. Discarding of some data on rain days are just some of the technical difficulties in interpreting any recorded data on such days due to errors that may arise. Another probable limitation would be the diameter of the micro-lysimeter (254 mm) being too small and therefore may impose a confinement such that a root crop like cassava may not realize its potential yield. This latter problem can be overcome by using larger diameter pipes to construct the lysimeter.

4. CONCLUSION

The lack of such vital water management data for cassava, especially in Ghana, warranted this particular investigation. This project has been able to establish the expected pattern in crop coefficient variation with the stages of crop growth. As earlier mentioned, the simplicity of the method lends itself to easy replication under different conditions to establish important water management parameters for cassava, at a relatively lower cost with less work involved. With the established K_c values at the different stages of crop growth and development, a reliable irrigation scheduling can be planned under the given conditions.

REFERENCES

Kochlar, S. L (1981): *Tropical Crops: A Textbook of Economic Botany*, Macmillan Publishers Ltd, 467 pp.

Purseglove, J. W. (1984): *Tropical Crop: Dicotyledons*, Longman Group Ltd, 718 pp.

Teare, I.D. and M. M. Peet (1983): *Crop Water Relations*, John Wiley and Sons Inc., 547 pp.

Michael, A. M. (1978): *Irrigation: Theory and Practice*, Vikas Publication House, 801 pp.

Shalhevet, J., A. Mantell, H. Bielorai and D. Shimshi (1981): *Irrigation of Field and Orchard Crops Under Semi-Arid Conditions*, International Irrigation Information Centre, (111C Publication No.1) 1981, Keterpress Enterprise Ltd, Jerusalem, 132pp.

Doorenbos J. and W. C. Pruitt (1975): *Crop Water Requirement*, Irrigation and Drainage Paper 24, FAO, Rome, 197 pp.

Hansen V.E., O.W. Israelsen, and G. E. Stringham (1979): *Irrigation Principles and Practices*, 4th Edition, John Wiley and Sons, 413 pp.

Jackson I.J. (1982): *Climate, Water and Agriculture in the Tropics*, 3rd Edition Longman Inc., New York, 288 pp.

Agbakpe, M. K. (2000): *Determination of crop Coefficient of Okra*, B.Sc. Thesis, Department of Agricultural Engineering, University of Science and Technology, Kumasi, Ghana, 54 pp.

Agodzo, S. K., J. W. Gowing and M. A. Adey (1996): *Evapotranspiration and Crop Coefficient Measurements Using Porous Clay Pot*. In: C.R Camp, C.J. Sadler and R.E. Yodder (eds.) Proceedings of International Conference on Evapotranspiration and Irrigation Scheduling. ASAE, pp 275 – 280.

Asare, E. (1999): *Arable Crops Production*, Unpublished Lecture Notes, Department of Crop Science, University of Science and Technology, Kumasi, Ghana.

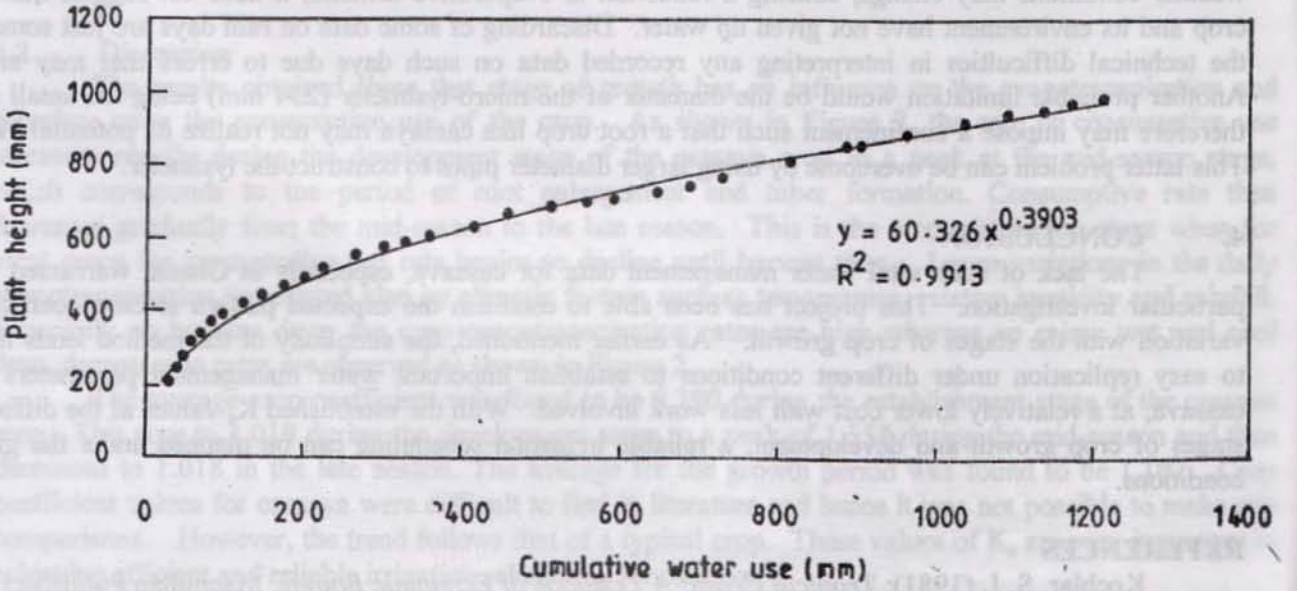

Figure 3: Plant height and cumulative water use relationship for cassava

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GOVERNMENT POLICY AND INSTITUTIONAL ISSUES ON TECHNOLOGY DISSEMINATION TO FARMERS IN IRRIGATION SCHEMES UNDER THE CONTROL OF RBDAs IN NIGERIA.

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ABSTRACT

Policy reforms and Institutional issues affecting the conduct of Agricultural Extension Support Services (AESS) for farmers operating in Public Sector Irrigation Schemes (PSISs) under the river Basin Development Authorities (RBDAs) from the early 1970s to late 1990s were reviewed. The effects of these policy changes on the performance of the PSISs and farmers benefits were also examined. Results showed that hitherto, RBDAs had absolute mandate for rural and infrastructural development for the PSISs and the surrounding communities as well as the promotion of irrigated agriculture through a comprehensive and functional arrangement for AESS. Unfortunately, they lost this mandate after the 1986 policy reforms. Under the revised and other subsequent policy reforms, farmers in the PSISs were left with little field advisory services. This situation discouraged most irrigation farmers from practicing irrigation farming leading to drastic reduction in area cropped (e.g. 84000ha. was recorded in 1985 as against 25000ha. in 1997). Consequently, majorities of the PSISs were unable to operate and maintain the already developed irrigated land (i.e. 99400ha.) as a result of principally inadequate funding and non-participation of farmers in the management of the scheme. The recently approved new policy on the operation of PSISs recognized the strategic roles of the RBDAs and the multitude and magnitude of problems that needed to be addressed.

KEYWORDS

Agricultural Extension Support Services (AESS), Public Sector Irrigation Schemes(PSISs), Water Users Associations (WUAs).

1.0 INTRODUCTION

The Federal Government in its effort to enhance national food security, create employment opportunities for the rural dwellers, and improve the development of agro-allied industries, and improved foreign exchange earnings in Nigeria, promulgated decrees establishing the River Basin Development Authorities (RBDAs) in the 1970s. This led to the construction of a number of dams and irrigation projects for irrigated agricultural production in the country. The Government, realizing the fact that irrigated agriculture is a specialized, capital intensive enterprise requiring the use of improved high yielding crop varieties, fertilizers, pesticides, agricultural machinery and above all, strong extension support services, mandated the RBDAs to provide such services to their farmers. This is in order to enhance successful irrigated agricultural production. Consequently, the RBDAs developed a strong extension delivery network within their respective areas of operation. Under this arrangement farmers were trained in modern irrigated agricultural practices in close relationships with some National Agricultural Research Institutes (NARIs), (Abubakar, et al. 1998a).

Support services rendered by RBDAs included provision of technical information that addressed the various crop production, soil and water management, farm inputs, tractor hire services, provision of credit facilities, and assisting farmers in produce marketing.

This arrangement continued until the introduction of unified extension services nationwide in 1986, under which the mandate for grassroots agricultural extension and other support services were transferred from the RBDAs to the State Agricultural Development Projects (ADPs). The ADPs were expected to provide extension services to the farmers in their respective states including those farmers within the irrigation projects being operated by the RBDAs (Mijindadi, et. al. 1993). The situation was not as expected across the country. This development gave rise to very a important question of optimal performance of the Irrigation Projects and the assurance of sound sustainable irrigated agriculture in the country.

The overall objective of the paper is to review the policy direction on agricultural extension delivery targeted at irrigated agriculture and to assess the performance of the extension delivery/services and their effect/impact on the performance of the irrigation farmers operating in the public irrigation schemes.

2.0 METHODOLOGY

The review was aimed to achieve the following objectives: to review the policy direction on agricultural extension delivery targeted at irrigated agriculture and to assess the performance of the extension delivery/services and their effect/impact on the performance of the irrigation farmers. Others include to assess the performances of irrigation infrastructures in public irrigation schemes under different policy regimes on agricultural extension delivery and to analyze the viability of sustainable irrigated agriculture for the country, and to proffer practical recommendations that would address the decline in the overall performance of irrigation development in the country. The review adopted the following procedure

- Administration of checklists to farmers in selected irrigation projects five RBDAs and two State-owned irrigation schemes (e.g. KRIP, BIP, LAIP, HVIP, TKIP, Wurno IP, Watari IP). Five questionnaires were administered to each of the 7 projects totaling to a total of 35. These farmers responded on their experiences and quality of extension delivery during the period of RBDA mandate as against the period of mandate shift to ADPs as well as during the period of policy revisal.
- Administration of checklists to seven irrigation project field staff and management
- Administration of checklists to the State ADPs'field staff and management who are supposed to provide extension support services to the irrigation farmers in the PISs (e.g. Kano, Jigawa, Zamfara, Anambra, Niger, Sokoto).
- Appraisal of field situations in the selected irrigation projects
- Desk review of feasibility reports, Regional Land & Water Resources Development Planning study report, position papers from FDI&D, NAERLS, and some RBDAs on the need to resuscitate agricultural extension delivery and support services in RBDAs' Irrigation Projects,
- Participation in organizing and synthesizing the outcome of series of National Seminars that discusses the issue of capacity under-utilization of the public irrigation projects.

The data was analyzed and classified into:

- Status of physical infrastructure of the IPs (e.g. functionality, area developed, area under cultivation, area abandoned),
- Quality of services provided to farmers (extension delivery, inputs provision, training etc)
- Level of productivity by farmers (e.g. increase in crop yield, increase in cropping intensities, increase in crop diversity, etc)

3.0 OVERVIEW OF SUPPORT SERVICES IN RELATION TO IRRIGATED AGRICULTURE

A declared objective of Nigerian Government is the drive for self-sufficiency in food production (FAO-World Bank, 1982). And the need to meet this objective is obvious. With more than 120 million human population, there is a lot of pressure on the agricultural sector. The situation is not helped by the

fact that the rate of growth of Nigeria's food production has been very low (FAO, 1991). Nigeria's food production has been growing at an average rate of about 2.5% per annum while demand for food has been growing at a rate of about 3.5% (Hundertmark, et al. 1999), thus, demand-supply gap exists. The government, in order to meet the objective of food self-sufficiency, has adopted various strategies (FAO, 1982), one of which, was the establishment of River Basin Development Authorities (RBDAs).

The Decree 25 of 1976, modified in section 4 of Decree No. 87 of 28th September 1979 gave mandates for RBDAs to go into overall development and optimization of land and water resources of their catchment areas. During this period, the RBDAs were allowed to go into agricultural related activities, which among others include the followings (Njokanma, 1999):

- Large scale multiplication of improved seeds, livestock and tree seedlings for distribution to farmers;
- Development of fisheries and improvement of navigation on the rivers, lakes reservoirs, lagoons and creeks in the Authority's area;
- Processing of crops, livestock products and fish produced by farmers in the Authority's areas in partnership with State Agencies and any other person;
- Undertaking mechanized clearing and cultivation of land for the production of crops and livestock;

The result in the projects of the RBDAs that carried out these mandates were encouraging (Abubakar, et al., 1998b; Babura, et al., 1992; Hundertmark, et al., 1999). Within the first decades (1970-1980) over 2000 in-service training on crop and water management for field extension staff were conducted involving more than 7000 field extension personnel. This no doubt, improved the quality of services rendered by the field level irrigation workers in the targeted parts of the country (Abubakar, et al 1998c). Table 1 summarizes the achievement recorded during this era (i.e. 1973 to 1985).

This situation was not sustained mainly due to policy changes and institutional reforms. (FAO-World Bank, 1982). Decree 35 of 1987 brought about a re-organization which streamlined the functions of all RBDAs re-focusing them on the development of surface and underground water resources to support agriculture, industries as well as for human consumption (Federal Military Government, 1993; FAO, 1991; and Njokanma, 1999). Below is the summary of the revised functions of the RBDAs

- Development of surface and under ground water resources for multi-purpose use;
- Flood and erosion control as well as water shed management;
- Construction/maintenance of dams/dykes, wells, boreholes and irrigation systems;
- Development of irrigation schemes for downstream crop production, fisheries development and enhanced participatory farming and management systems.

That particular policy reform strictly limits the activities of RBDAs to water resources development and distribution with less attention to farmer's key problems. The situation forced most RBDAs to abandon among their major responsibilities, extension delivery and support services, provision of farm inputs, direct crop production, etc. The situation manifested itself in dwindling resources (human and material) as well as disappointing performance by the RBDAs. Table 2 summarizes the performance of the RBDAs during the period of mandate change (1986 –1995). For instance Babura, et al. (1992) reported that in 1990, out of 99,440ha developed by RBDAs, only 52,175ha (representing 53%) was cropped (Federal Military Government, 1993). Despite the review of policy to resuscitate the previous functions of RBDAs, the agencies find it difficult to resume all field activities hitherto undertaken as a result of lack of field advisory staff who were retrenched earlier (Musa, et al. 1999). Thus the aggregate performances of the RBDAs did not show a significant improvement. In 1997 the estimated hectares put under cultivation by all RBDAs dropped to below 25,000ha representing less than 27% of the initially developed area (Hundertmark, et al. , 1999; Musa, et al., 1999; and APMEU and NAERLS, 1997). Table 3 presents the performance of all RBDAs between 1996 and 1999. This situation continued to worsen to a point where some RBDAs could not provide the enabling environment for the farmers in the irrigation projects to cultivate up to 20% of their land (Abubakar, et al. 1998d).

4.0 PRESENT STATUS OF AGRICULTURAL EXTENSION SERVICES IN IRRIGATION PROJECTS

With the government policy where the RBDAs have their role in irrigated agricultural production restricted to only water resources management, there are strong indicators to suggest that the policy succeeded in creating a vacuum in extension support services within the Irrigation projects Areas (IPAs). The ADPs' attitude to the farmers in the IPAs over the years point to the fact that they (ADPs) do not seem to posses the capacity to execute the mandate of providing grassroots agricultural extension advisory services in the IPA's. As a result, extension support services to farmers in these IPA's became deficient, while appropriate linkages with research centers also became very weak and in some cases totally collapsed. The situation with regard to extension support services was such that virtually most farmers were neither served by RBDAs nor by the ADPs (Abubakar, et al., 1998b).

A study was conducted by the National Agricultural Extension and Research Liaison Services (NAERLS) under a World Bank Assisted Project (unpublished) in Kano River Irrigation Project (KRIP), Kano State and Bakolori Irrigation Project (BIP), Zamfara State in 1997. The study established that farmers have been completely neglected by the organized extension delivery services especially the ADPs who have the primary responsibility for the activity. Results from the study showed that not a single farmer interviewed indicated receiving information on operation and maintenance of the irrigation system or on improved crop and water management practices from the ADPs, since the disengagement of the RBDAs from rendering these activities in 1987. The response of Kano and Zamfara States ADP management on the issue confirmed the farmers' claims. The ADPs confirmed that even though the Irrigation Project Areas (IPAs) are within their geographical area of operation, extension officers (who sometimes settled in the same communities with the farmers operating in IPA) rarely attends to the farmers in these areas in favour of the farmers in the fadama sites. Most farmers also rated radio, television and extension publications, low, as sources of information. This clearly confirmed that the ADPs seldom reflect on the need of the farmers within the irrigation schemes when organizing their radio or television programs which enlighten farmers on how to solve problems related to irrigation farming practices.

The non participation of the ADPs in rendering such services to the IPAs also manifested itself in the lack of contact with National Agricultural Research Institutes (NARIs). Vital outputs from these centers especially the extension publications that address farmers' problems such as pamphlets, posters, leaflets, extension guides, etc. produced in local languages are no longer distributed to interested end users.

5.0 UNIFIED EXTENSION AND IT'S IMPLICATION FOR IRRIGATION PROJECTS.

The unification of agricultural extension services was aimed at providing a more efficient and cost effective field advisory services to the teeming population of Nigerian farmers. ADPs are the implementation agencies charged with this responsibility at the grassroots level.

This policy reform brought along with it other vital institutional and administrative issues. Principally, among them are the restriction of RBDAs' mandate to only water resources management, on one hand and unification of extension services for both wet and dry season cropping as well as fishery, animal husbandry and agro-forestry which are far from being accomplished at the field level in majority of the states (particularly within the IPAs). This workload requires well-trained personnel supported by NARIs to discharge the responsibility of grassroots extension delivery, as was the case previously (Abubakar, et al., 1993); Abubakar et al., 1998b; Abubakar et al.,1998c; and NAERLS, 1997). Equally responsible for this situation includes the inadequacy of technologies, ineffective dissemination methodologies and poor packaging of technologies in both irrigation engineering and irrigation agronomy subject matters. In areas where research has been carried out, there exists a backlog of technical innovations, new crops and production techniques that have promise for adaptation in irrigated agriculture, but are yet to be introduced to farmers. This problem is partially attributable to the dearth of skilled and experienced manpower in the area of irrigation extension because of complete absence of a training institution on the subject matter in the country. The last such institution was the college of

Agriculture, Bakura. Table 2 summarizes the sum total of the neglect of the farmers in the PISs. As a result of this situation and despite the good government policy to assist small farmers, the farmers in the affected IPAs have been unable to realize the stream of benefits anticipated (FAO, 1991; Federal Department of Irrigation & Drainage (FDI&D), 1999; and Musa, 1999). Solutions to these problems are vital to the development of an effective and efficient irrigated agriculture in the country.

6.0 EFFECTS OF THE VARIUOS POLICY REGIMES ON THE PERFORMANCE OF RBDAS

There are handfuls of evidences of capacity under-utilization as a result of the negative effects of the period of mandate change. During a series of field trips in 1998/99 to appraise some existing irrigation schemes for rehabilitation by the defunct Petroleum Trust Fund, it was observed by Enwerem (2001) that, in many of the projects, the land was only fully utilized during the wet season while very little of the land was cultivated during the dry season. In a few of the cases, such as in the Lower Anambra Irrigation Project, the problem was lack of spare parts for the water pumps. In some other cases such as the South Chad Irrigation Project, the pumping system had broken down completely due to scarcity of diesel to run the generating sets. In Bakolori Irrigation Project only 400ha of the 15, 000ha sprinkler system was cultivated during that year. Enwerem (2001) also observed that even in the surface gravity systems, the available net irrigable area was not fully cultivated in many cases. For example, in the 8000ha surface gravity part of Bakolori irrigation project only 3,900ha was irrigated during the dry season. In Kano River Irrigation the figure was 6863 ha out of 13,286ha, while in the Hadejia Valley Irrigation Project only 645ha out of 2150 irrigable hectare were cultivated. The operational status of some key irrigation projects as seen during a field visit in 1998/99 is shown in Table 4 below.

The figures in the Table 4 show that the in the case of Bakolori, a cropping intensity of 96% was achieved during both seasons instead of 200%. This is equivalent to 48% capacity utilization or 52% capacity under utilization. In KRIP the cropping intensity was 147% (that is 73.5 capacity utilization) while in HVIP the cropping intensity was 122% (or 61% capacity utilization). The overall cropping intensity in the four schemes in the table during that year was 28% during the dry season and 85% during the wet season, giving a combined cropping intensity of 113% as compared to 200% (56.5% capacity utilization).

At a national level, Adeniji (2001) reported a similar effect. Table 5 shows the 1999/2000 statistics on the status of irrigation capacity utilization and levels of irrigation achievement Nigeria. The latter was defined as a percentage ratio of after developed to planned area or that of irrigated to planned area, while the former was defined as a percentage ratio of area irrigated to that developed (Adeniji, *2001).*

The statistics in table 5 suggest that out of the 100,300ha developed as at the end of the 1999/2000 season, only 35,127ha were irrigated leaving more that 65,000 ha un-utilized. For the obvious reasons of greater degree of aridity and perhaps greater susceptibility to droughts in the northern zone, the table suggests that there is a preponderance of irrigation activities in the North. For example, capacity utilization in the North (37.14%) is more than five times that of the South (6.94%), Achievement I is more than three times while achievement II is over seventeen times. All in all however, the levels of the three indices are too low for both north and south as well as for the country as a whole. Although the reason (s) for this situation may vary from project to project to project or from zone to zone, it is generally believed that they may not be unconnected with inadequate funding for the operation, maintenance and management of the various irrigation projects.

7.0 EXTENSION SUPPORT SERVICES IN IPAs UNDER RBDAs: THE WAY FORWARD

To reverse the present situation enumerated in the above discussion, farmers in IPAs need specialized extension workers who are exposed to irrigation system operation and maintenance, on-farm water management, crop production and management practices, improved post-harvest practices, socio-economic aspects, etc.

In order to ensure the sustainability of the irrigation schemes under the RBDAs, the issue of resuscitation of extension support services as part of their mandate is very crucial. Irrigation farmers need

continuous flow of improved agricultural and irrigation techniques for profitable crop production and efficient system utilization and management. The extension support services should form part of the package of services being provided to the farmers by the RBDAs (Abubakar, et al., 1998b and Kolawole, 1992).

What is obvious is that, management of irrigated agricultural production systems has proven more difficult than was foreseen. While emphasizing the critical role of provision of adequate extension services, a participatory and effective system operation and maintenance and crop production and marketing approaches that is fully supported with an efficient cost recovery mechanism for IPAs must be evolved. These put together will raise the irrigation benefits in terms of the total area irrigated, level of crop yield and production per unit area, system performances, and environmental friendliness of the IPAs and income accrued from irrigation investment.

It is gratifying to note that the present federal government has formally returned to the RBDAs their hitherto mandate of agricultural extension support services and the other complementary roles as well as reconstituting the management teams of most RBDAs (FDI&D, 1999). It is the belief of the author that all these were done with good intentions to bring back the glorious days of impressive irrigated agriculture in this country. It is however expected that the RBDAs will recognize the critical roles they are to play in achieving the set objectives of food security and poverty alleviation in the country. To achieve this, they must put in place the necessary administrative structures, reorganize and very importantly, re-orient their staff to understand their new roles/responsibilities and challenges. It is pertinent for the RBDAs to note that they must enhance their institutional capacities in order to be able to address the lapses identified under the previous Government policies particularly as it relates to farmers. These agencies must also be able to accommodate the topical issues of Participatory Irrigation Management (PIM) which both the agencies and the farmers must strive hard to understand and implement if the IPs are to be sustained in the country (Kolawole, et al.,1992).

CONCLUSION

The resuscitation of Agricultural Extension Support Services in RBDAs, controlled Irrigation Projects is a positive policy reform and is welcomed after 13 years of inactivity (FDI&D, 1999). The laudable mobilization and institutional efforts made in drawing the attention of the concerned authorities to the ills, losses and damages the previous policy brought to both the farmers, the authorities, and the country, can be said to be very rewarding. It is however necessary to caution, at this point, that there should be consistency in government policies and other administrative and institutional arrangements regarding the functions of RBDAs. This is because past experiences showed that both the RBDAs and eventually the farmer's end up confused with the intermittent and inconsistent policy changes that usually bring huge economic loss to all.

RECOMMENDATIONS

To achieve maximum benefits from the recent Government policy reforms and new institutional and administrative changes, the government must create the enabling environment that would allow the RBDAs to:

- sensitize all farming communities around existing irrigation schemes to start practicing irrigation farming;
- mobilize the irrigation farmers in all irrigation schemes to form Water User Associations (WUAs);
- facilitate the institutionalization of all WUAs operating in irrigation schemes into Legal entities;
- re-orient their staff on the new roles and challenges for the practice of participatory irrigation management concept;
- establish a continuous capacity-building programme for both the WUA members and irrigation project field staff;
- facilitate the profitable production of specific crops adaptable to the various ecologies by the WUAs under contract-growership and for exportation;

- establish price guaranty scheme that would ensure profitable marketing of agricultural produce directly by farmers for higher income,
- facilitate timely sourcing of farm inputs at affordable prices and of bank loans at low interest rates; and very importantly,
- encourage active and closer linkages between RBDAs and the National Agricultural Research Institutes (NARIs) on one hand and between the RBDAs and the ADPs on the development of irrigated agriculture in the country. Both linkages would certainly ensure effective and efficient irrigation technology development and transfer to end users and reliable feedback to the NARIs for necessary action.

REFERENCES

Abubakar, S. Z., Arokoyo, T. J., Yiljep, Y.D., Zaria, M.B. (1993). Research and Extension Priorities in Irrigation Technology Development and Transfer in Nigeria. Proc. of a NSI Research Priorities for Nigeria (eds.) Nwa & Pradhan, Uni-Ilorin., Pp. 58-62.

Abubakar, S.S. and Abubakar, S.Z. (1998b). Resuscitation of Agricultural Extension Support Services in RBDAs' controlled Irrigation Projects. An invited Memo presented at a meeting of National Sub-Committee on Irrigation and Drainage held between 19th – 20th October and 9th November both at UNRBDA, Minna.

Abubakar, S.S. (1998c). The Role of NAERLS in Irrigation Extension Support Services in Nigeria. Presentation at the National Irrigation and Drainage Seminar held between 14th – 16th April at NAERLS Conf. Hall, A.B.U., Zaria.

Abubakar, S.Z. Abubakar, S.S. and G.B. Murtala (1998a). Irrigation Extension and Training in Nigeria: NAERLS-Two-Decades of Support. Presentation at the 1st National Irrigation Week held between 24th – 27th March at Kano State House of Assembly, Kano.

Abubakar, S.Z., A. A. Ramnalan and O.J. Mudiare (1998). Some Effects on Agricultural Productivity of Jakara River Irrigation Project (JRIP) due to Urban and Industrial Waste Dumping in Jakara Dam Reservoir (JDR). Paper presented at the 12th National Seminar on Irrigation and Drainage held between 14th – 16th April in Zaria.

Adeniji F.A. (2001). Operation and Maintenance Constraints to Capacity Utilization for Sustainable Irrigation Development in 21st Century Nigeria. Presentation at the national workshop on sustainable irrigation Development in Nigeria held at Giginya Hotel, Sokoto from 2nd to 6th June 2001.

APMEU and NAERLS. (1997). Development of Irrigated Area for Dry Season Farming in Nigeria. Report on 1996/97 dry season farming submitted to FDA Abuja, FACU Abuja, and distributed to all states ADPs Pp. 15-23.

Babura, R.S.A and J.P. Omotowoju (1992). Farmer Participation in Irrigation Development and Management: Experiences from KRIP. Presentation at the National Workshop on the Impact of Irrigation Projects in Nigeria's Environment held at O.A.U., Ile-Ife, Nigeria.

Enwerem, C. (2001). Low Capacity Utilization in Public Sector Irrigation Schemes and its Effects on Irrigation System Cost Recovery and Funding. Presentation at the national workshop on sustainable irrigation Development in Nigeria held at Giginya Hotel, Sokoto from 2nd to 6th June 2001.

FAO (1991). Nigeria: Irrigation Sub-sector Review, Report No: 89/91/CP-NIR 45SR

Federal Department of Irrigation & Drainage (FDI&D) (1999). Guidelines on National Irrigation and Drainage Policy for Nigeria. 3rd draft policy document circulated to members of National Sub-Committee on Irrigation and Drainage for input at an internal ministerial workshop held between 28th – 29th January at NWRI Kaduna.

Federal Military Government (1993). Water Resources Decree No. 101. Supplement to Official Gazette Extraordinary No. 27 Vol. 80, 1st September, 1993. Part A.

Food and Agricultural Organization-World Bank (FAI-WB), (1982). Irrigation and Reclamation Development Policies: A Food Production strategy for Nigeria. Technical Report AG: TCP/NIR/0103.

Federal Department of Irrigation & Drainage (FDI&D) (1999). Approved New Policy on the Operation of RBDAs in Nigeria. Memo presented by the Hon. Minister of Water Resources at the 16th National Council on Water Resources held between 26th – 29th November in Calabar.

Hundertmark, W. and Abdourahmane, A.T. (1999). Analyzing Nigeria's Food and Water Resource Policy: Scenarios and Implications. Presentation at International Seminar on *Performance of Large and Small-Scale Irrigation Schemes in Africa* held between 15th – 19th November at Abuja, Nigeria.

Kolawole, A. (1992). Commercialization and the Future of RBDAs in Nigeria. Research report from Center for Social and Economic Research, A.B.U., Zaria.

Maurya, P.R., Owonobi, J.J. Kumar, V. Yayok, J.Y., and Abdulmumini, S. (1991). Farmer Participation in Irrigation Development and Management. Proc. Of a National Workshop held between 7th – 8th May at the I.A.R., Samaru, Zaria.

Mijindadi, N. B., Umar, Q., and Tyem, M. N. (1993). ADP Experiences with FADAMA Development: Achievements, Problems and Prospects. In Nwa, E.U., and Pradhan, P. (eds.) Proc. of the National Seminar on Irrigation Research Priorities for Nigeria. P;. 44-50.

Musa, I.K. (1999). Irrigation and Drainage Challenges of the 21st Century: Re-engineering of Public Irrigation Systems for Sustainability. Presentation at the Orientation workshop organized for the New Management of RBDAs held between 25th – 26th October at NWRI, Kaduna.

NAERLS. (1994). Adoption Study on Water Management Practices in KRIP Kadawa, Kano State and BIP T/Mafara, Zamfara State. Report Submitted to NARP Abuja (World Bank sponsored Project) Pp. 13-42.

Njokanma, I. R. (1999). Legal Aspects of RBDAs: Establishment and Functions. Presentation at the Orientation workshop organized for the New Management of RBDAs held between 25th – 26th October at NWRI, Kaduna.

Table 1. Achievements of RBDAs in Nigeria during the period of Mandate (1973-1985)

S/N	Description of achievement	Quantification	Remarks
1.	Regulated crop production	>12,000.00 ha in all RBDAs	that allowed Intensive and technology-based cultivation
2.	Emergence of 3-cropping in one calendar year	>6 RBDAs adopted this	Drastically reduce rural urban migration
3	Optimal crop productivity and higher returns to farmers	Crop yields increased by 45%	Superior crop varieties were adopted leading to higher income Realized by farmers
4.	Enhanced farm inputs delivery system	All RBDAs	Timely provision, in adequate quantity and on credit to the farmers
5	Effective extension delivery for farmers	Staff: farmer ratio of 1: 50	Effective supervision and demonstration of packages
6	Higher market opportunities for farmers produce	All RBDAs have private companies	This made the regulated production enforced by RBDAs ineffective for the good of farmers
7.	Rapid expansion of infrastructure in	700,000ha 25 dams 500 km roads	Land development, storage system, Road network, buildings, Boreholes, etc
8.	Establishment of Bakura college of irrigation agronomy	In 1972	over 1000 middle cadre personnel were trained for the IPs
9	Conducted over 50 seasonal in-service training sessions for staff of ministries, RBDAs across the country	Over 7500 staff Were trained Between 1975 to 1988	Served as incentive or motivation to field staff working with RBDAs thus Their outstanding dedication
10	Strong and constant contact between Research, extension and farmers for effective technology generation and transfer	All RBDAs allocated trial fields to research centers	Constant dissemination of technologies addressing farmers' problems
11	Staging of National Irrigation & Drainage Seminars since 1972	A total of 11 were Held between 1972 and 1991	This helped in promoting functional interaction amongst Professional and policy makers

Table 2. Performance of RBDAs in Nigeria during the period of Mandate shift 1986-1995)

Level of Performance in Public Irrigation Schemes
▪ Existence of a backlog of technical innovations, new crops and production techniques that have promise for adaptation but are not introduce to farmers.
▪ inadequacy of technologies & ineffective dissemination methodologies ▪ poor packaging of technologies in both irrigation engineering and irrigation agronomy
▪ dearth of skilled and experienced manpower in the area of irrigation extension
▪ complete absence of a training institution on the subject matter of irrigation agronomy in the country.
▪ neglect of the farmers in most public irrigation schemes (PISs) by the extension delivery system ▪ rising water tables on farmers fields in most PISs ▪ appearance of waterlogged in farmers fields ▪ abandonment of irrigated fields by farmers in the affected areas in PISs ▪ increasing salinity level of the groundwater ▪ increase in salt-content in the project areas soils in most PISs ▪ High risk of crop failures ▪ Decline in irrigated area, cropping intensity ▪ Decline in crops diversity and crop yield ▪ Decline in farm incomes, and cost recovery
▪ Deterioration of infrastructure, low funding, low crop productivity low cost recovery ▪ Unable to sustain the public irrigation schemes

Table3. Performances of RBDAs in Nigeria during the period of revised policy(1996-1999)*

River Basin Development Authorities**	Developed Area (ha)		Area under irrigation (ha)		Performance ratio (%)	
	Before 1996	By 1999	By 1996	By 1999	By 1996	By 1999
Anambra-Imo	4021	3900	3850	67	95.7	01.7
Upper-Benue	13,150	8,860	7,130	3400	54.2	38.4
Hadchia-Jama'are	17,100	18,325	14,150	16,213	82.8	88.5
Chad-Basin	29,330	23,360	4,350	2,550	14.8	10.9
Sokoto-Rima	26,700	23,570	9,583	5,420	35.9	22.9
Cross-River	617	644	72	95	11.7	14.8
Benin-Owena	832	818	534	207	64.42	25.3
Oshun-Ogun	410	291	110	76	26.8	26.1
Niger-Delta	452	722	212	141	46.9	19.5
Upper-Niger	2,885	4,450	310	345	10.7	07.8
Lower-Benue	1020	1.315	137	45	13.4	03.4
Lower-Niger	860	720	400	230	46.5	31.9
TOTAL	**97,377**	**86,915**	**39.090**	**28,798**		

*Source: FDI & D, FMWR, at in-house workshop held at NWRI, Kaduna, October 1999.
**The figures are for all the public schemes under the authority

Table 4: Operational Status of some Active Irrigation Projects under RBDAs

Irrigation Projects	Initial Proposal (ha)	Developed command (ha)	Currently Irrigated (ha)	Rainfed (ha)	Abandoned (ha)
BIP	30 000	23 000	4 300[2]	18 000	700
KRIP I	21 850	13 286	6 865[3]	12 700	4 000
LAIP	5 000	3 850	NIL[4]	3 100	68
HVIP	12 500	2 150	645[5]	1 985	25
TOTAL	69 350	42 286	11 810	35 785	4 793

1 Based on feasibility study reports
2 Based o the Regional Land & Water Resources Development Planning Study (400 ha under sprinkler and 3 900 ha under surface system).
3 Based on field observations and discussions with KRIP staff during the Sustainable Irrigation Management Study, 1998/99.
4 Based on field observations and discussions with LAIP staff during the Sustainable Irrigation Management Study, 1998/99
5 Based on 1998/99 dry season crop survey conducted by HVIP Management, which determined that only 30% of the command area was cultivated.

Table 5: Status of Irrigation Capacity Utilization and Achievement in Nigeria as at the End of 1999/2000 Season (Source: FDID, 2000)

Zone		Southern	Northern	Country
No. of Schemes	(A)	35	57	96
Area planned (ha)	(B)	79,759	333,635	413,394
Area developed (ha)	(C)	7,030	93,270	100,300
Area Irrigated (ha)	(D)	488	34,639	35,127
Capacity Utilized (%) {100(D)/(C)}	(E)	6.94	37.14	35.02
Achievement I (%) {100(C)/(B)}	(F)	8.81	27.96	24.26
Achievement II (%) {100(D)/(B)}	(G)	0.61	10.38	8.50

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PRELIMINARY STUDIES OF SOME AGRONOMIC AND DESIGN FACTORS RELEVANT TO THE MECHANIZATION OF YAM SETT PLANTING ON RIDGES

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ABSTRACT

Mechanization of the planting operation has been a major limiting factor in the mechanization of yam production. Laboratory and field experiments were carried out to explore a method for mechanizing the traditional practice of planting yam setts on hand-made mounds. The laboratory experiments were carried out using a model planting unit which consists of a delivery manifold, integral with a furrow opener, for depositing yam setts within pre-formed ridges and a trailing pair of ridger discs for covering up the deposited setts with soil. With linear geometrical parameters expressed as fractions of the disc diameter D, different experimental configurations of the model planting unit were tested in a soil bin facility. The experimental conditions considered included a speed range of 0.6 – 5.4 km/h, a longitudinal distance range of 0.34D – 0.92D between the leading disc and the delivery manifold, lateral distances of 0.42D and 1.24D between disc centres and disc and tilt angle ranges of 18 – 54° and 18 – 30°, respectively. For the field experiments, special profile meters were constructed and used to monitor progressive changes in mound and ridge profiles in the field. The best combination of sett placement and final ridge profile was obtained at a planting speed of 2.7 km/h and for a planting unit configuration featuring a lateral distance of about 1.24D between disc centres, a longitudinal distance of about 0.92D between the leading disc and the delivery manifold, disc angles of about 35° and tilt angles in the range 18° – 23°. Soil loss from ridges during the first few rains after ridge formation was substantially reduced by using cylindrical rollers trailing the ridger discs.

KEYWORDS

Preliminary Studies, Agronomy, Design, Yam Set Planting

1. INTRODUCTION

Yam, a tuber crop, constitutes a major staple food in some parts of the tropics and is also known to have a longstanding socio-cultural significance in the lives of some communities (Hahn *et al.*, 1987; Degras, 1993). Yams are grown principally for the carbohydrate they provide. Indeed, it has been reported that yams account for about 20 per cent of the daily caloric intake of Nigerians (Iwueke *et al.*, 1983).

The total world production of food yams is estimated at 20 – 25 million tonnes per year (Hahn *et al.*, 1987). Of this, an estimated 15 million tonnes are produced annually in Nigeria alone from about 1.5 million hectares of farm land (Okoli, 1987). Yams may be cropped using one of three types of planting material. These are small whole tubers called "seed yams" (100 – 1500 g), tuber portions called "setts" which are obtained by cutting large whole tubers into head, middle or tail pieces (100 – 150 g) and very small pieces called "minisetts" (about 25 g or less) which are specially prepared by cutting selected 'mother seed' yam into pieces, treating them in a fungicide/insecticide suspension and sprouting them in moist sawdust. Since seed yams are whole yams, they are often consumed and, consequently, are less readily available as planting material. Indeed, this shortage and the associated relatively high cost of seed yam planting material informed the development of the minisett technique (Okoli *et al.*, 1982). Minisetts as planting material require some specialised cultivation activities beyond the normal scope of peasant farmers. In comparison with seed yams and minisetts, traditional yam setts as planting material are

culturally accepted, readily available and do not require specialised cultivation activities. Yam production in Nigeria is mainly carried out by peasant farmers who rely on a portion of their previous season's harvest, usually between 25 and 33 per cent (Hahn *et al.*, 1987), as the source of planting material for the following season.

Large tubers are preferred in the forest belt of the yam zone (Cameroon, Nigeria, Benin, Ghana and Ivory Coast), and they necessitate using large planting setts ranging from 100 to 1500 g in weight (Hahn *et al.*, 1987). Although yams are occasionally planted in holes or on flat ground, mounding is the most common practice in traditional agriculture (Onwueme, 1978). Indeed, with the exception of a few areas where soils are deep and yams may be grown on flat ground, they are invariably planted on hand-made mounds (Hahn *et al.*, 1987). These mounds provide ample loose fertile soil for root and tuber growth. Although a height of about 50 cm is common in many cases (Onwueme, 1978), the size of mound used varies from place to place and mounds of 1 to 2 m height and radius of 2 to 3 m have been reported (Hahn *et al.*, 1987).

The fact that the traditional methods of cultivating yams are arduous, labour intensive and time consuming is well attested to in the literature (Nwuba and Kaul, 1987; Hahn *et al.*, 1987; Odigboh and Akubuo, 1991). Yet, the preponderance of research activities on yam production to date, have been focused on yam agribiology, breeding, pests and diseases, economics and sociology (Osuji, 1985; Coursey, 1983). In comparison, very little is reported in the literature on the mechanization of yam production. Vandevenne (1973) reported on stanchion ridgers for mechanizing the planting of yams and Odigboh and Akubuo (1989, 1991) reported work on the design and development of automatic planters for planting minisetts and seed yams, respectively. Although the latter contributions report some measure of success, albeit limited, in addressing the mechanization of yam planting using minisetts and seed yams as planting materials, it is clear from the foregoing review, that the development of a method and equipment, for mechanizing yam planting on mounds using traditional setts would be a major breakthrough in the mechanization of yam production. This paper explores some agronomic and other factors of prime importance to the successful development of a method and equipment for mechanizing yam sett planting on mounds. Key factors were investigated in the laboratory using a model planting unit and a soil bin facility whilst field experiments with mounds and ridges were carried out to investigate agronomic factors.

2. EXPERIMENTAL METHODS

2.1.1. The model planting unit

Although the complete yam sett automatic planter will comprise a metering system as well as a planting unit, the scope of the present investigation is limited to laboratory tests of the model of the planting unit. Figure 1 shows the layout of the model planting unit as used in the soil bin experiments. The planting unit basically consists of a delivery manifold and a pair of 300 mm diameter ridger discs, both of which are mounted on a rectangular frame. The lower end of the delivery manifold consists of an inverted "V" shaped furrow opener followed by a hollow rectangular portion open at the rear. Thus, the furrow opener opens the ridge top while the opening at the rear of the rectangular portion allows deposited setts to nest in the opened ridge top. The frame is supported by 4 wheels (2 on either side) that run on parallel wheel tracks on both sides of the soil bin. Figure 2 shows the model planting unit during a typical test run.

2.2. Soil bin experiments

Since the traditional practice of mound making is not amenable to mechanization with commonly available machinery and equipment, planting on previously formed ridges was adopted as the closest simulation of the agronomic planting conditions afforded by mounds. Preliminary trial runs of the model planting unit were carried out at 0.6, 1.1, 2.7, 3.6 and 5.4 km/h forward travel speeds in the soil bin. Due to poorly formed ridges and sett displacement at the higher speeds, an optimum speed of 2.7 km/h was identified and subsequently maintained in the tests of different experimental configurations of the planting unit (i.e., Tests 1 – 10 in Table 1). The soil bin experiments were carried out to investigate two methods of planting namely planting on ridges and planting on flat ground. In the former of these

methods, an initial ridge was formed prior to the actual test run of the model planting unit. In operation, model setts were manually dropped into the delivery manifold at pre-determined intervals. The trailing ridger discs then covered up the deposited setts with soil. The final height and base width of the ridge after sett placement and the depth of sett placement within the ridge were measured for each experiment. Qualitative assessments of lateral and longitudinal sett displacement within the ridge were obtained through careful observation.

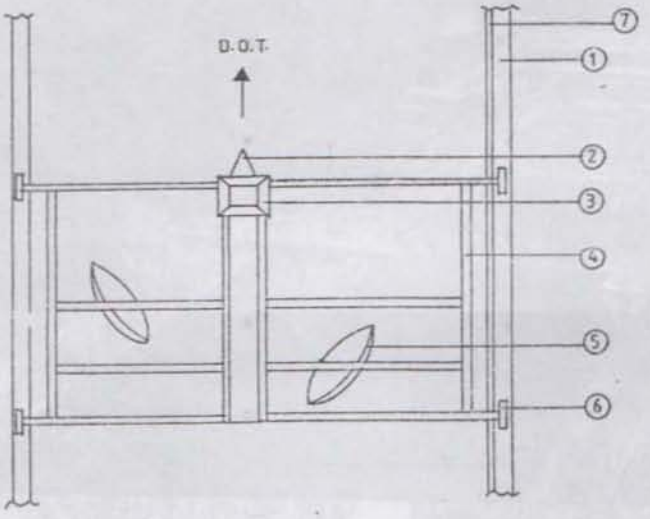

Fig. 1: Model Planting unit layout in soil bin experiments. 1, wheel track; 2, furrow opener; 3, delivery manifold; 4, tool frame; 5, ridger disc; 6, frame support wheel; 7, soil bin

2.3. Field experiments

Experiments were carried out to examine the effect of successive rainfalls on mound and ridge profiles in the field. The mound was manually prepared in the traditional way using a hoe. A standard pair of mechanical ridger discs, fully mounted on a tractor, was used to make two different ridges. Whereas the first ridge (Ridge I) was made by simply pulling the ridger discs through the soil, an additional attachment, namely a set of special cylindrical rollers located to the rear of the ridger discs, was employed in making the second ridge (Ridge II). The cylindrical rollers were used to make the soil more compact and firm in an attempt to reduce soil loss due to rainfall erosion.

Special profile metering devices were constructed to facilitate cross-sectional measurements of the mound and ridge profiles. Figure 3 is a schematic illustration of a typical profile meter. A profile meter consists of two vertical bars linked by two horizontal cross bars as shown in Fig. 3. Each profile meter was installed such that the vertical bars, spaced 900 mm apart, stood astride the ridge or mound. The horizontal cross bars span the width of the ridge (or mound) each having eight holes placed at regular intervals of 100 mm from each other. Each profile meter was assembled such that corresponding holes on the horizontal cross bars were aligned in the vertical direction. Cross-sectional ridge profile measurements at a point along the ridge profile were subsequently taken by inserting a measuring rod into the ridge at that point, through a particular pair of consecutive (i.e., aligned) holes. For each of the ridges, profile meters were installed at two separate locations. Owing to the peculiar shape of mounds (i.e., conical heaps), the profile meter used for the mound was fitted with an additional pair of cross bars such that the mound profile was measured along two mutually perpendicular cross-sections. The profile meters for the two different ridges and the mound are shown in Figs. 4 (a) – (c) respectively.

Measurements of the ridge profiles were taken on the day the ridges were made and, subsequently, after every rainfall. From the data collected, the change in the ridge profile at a particular point was determined after each successive rainfall by calculating the ratio of the profile height after a particular rainfall (PH_i) to the initial profile height (PH) at that point. A non-recording rain gauge was used to measure the depth and intensity of each rainfall.

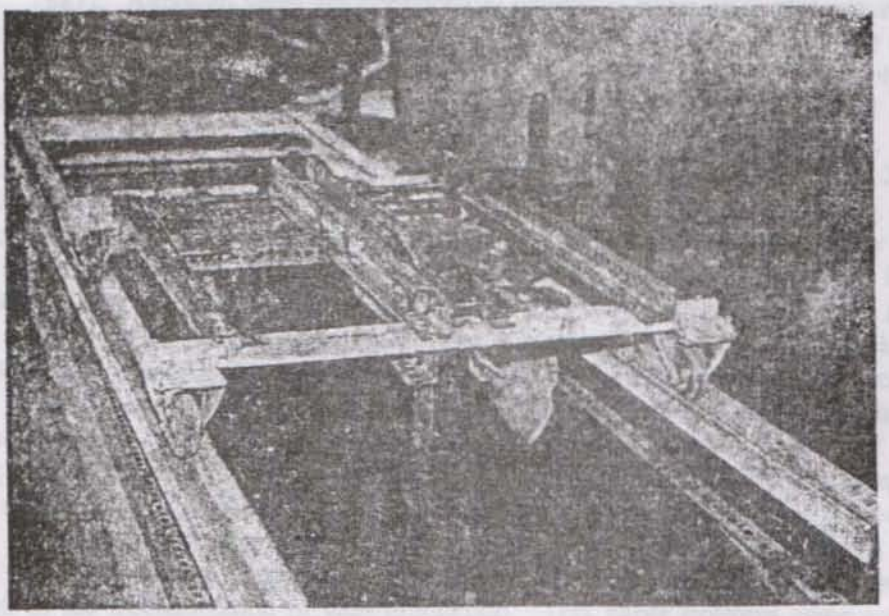

Fig. 2: The model planting unit during a typical test run

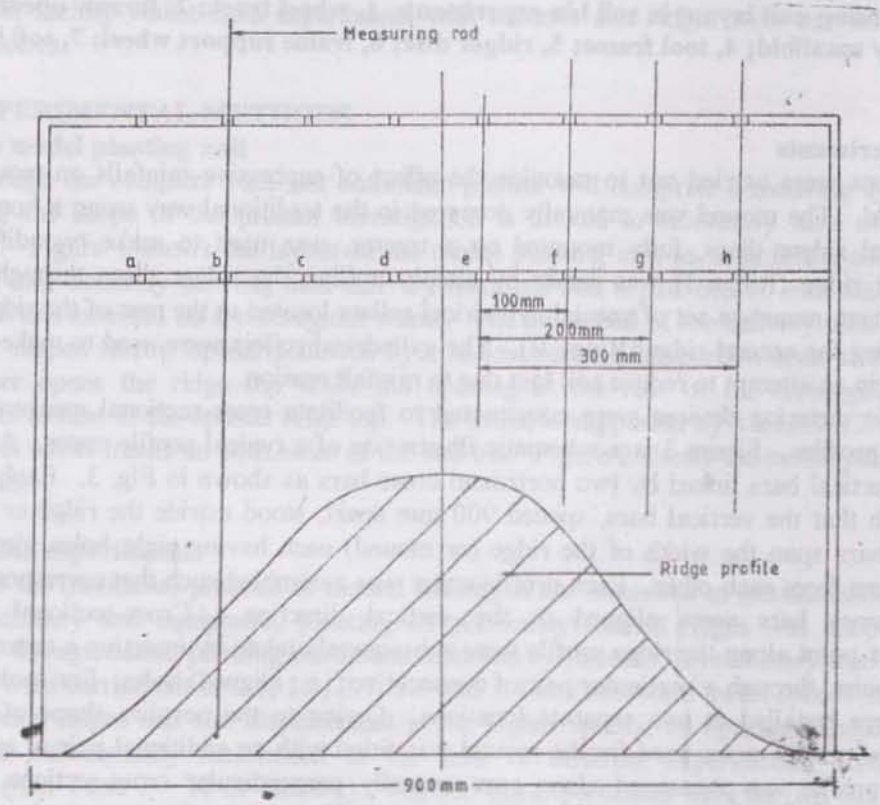

Fig. 3: Schematic illustration of a typical profile meter

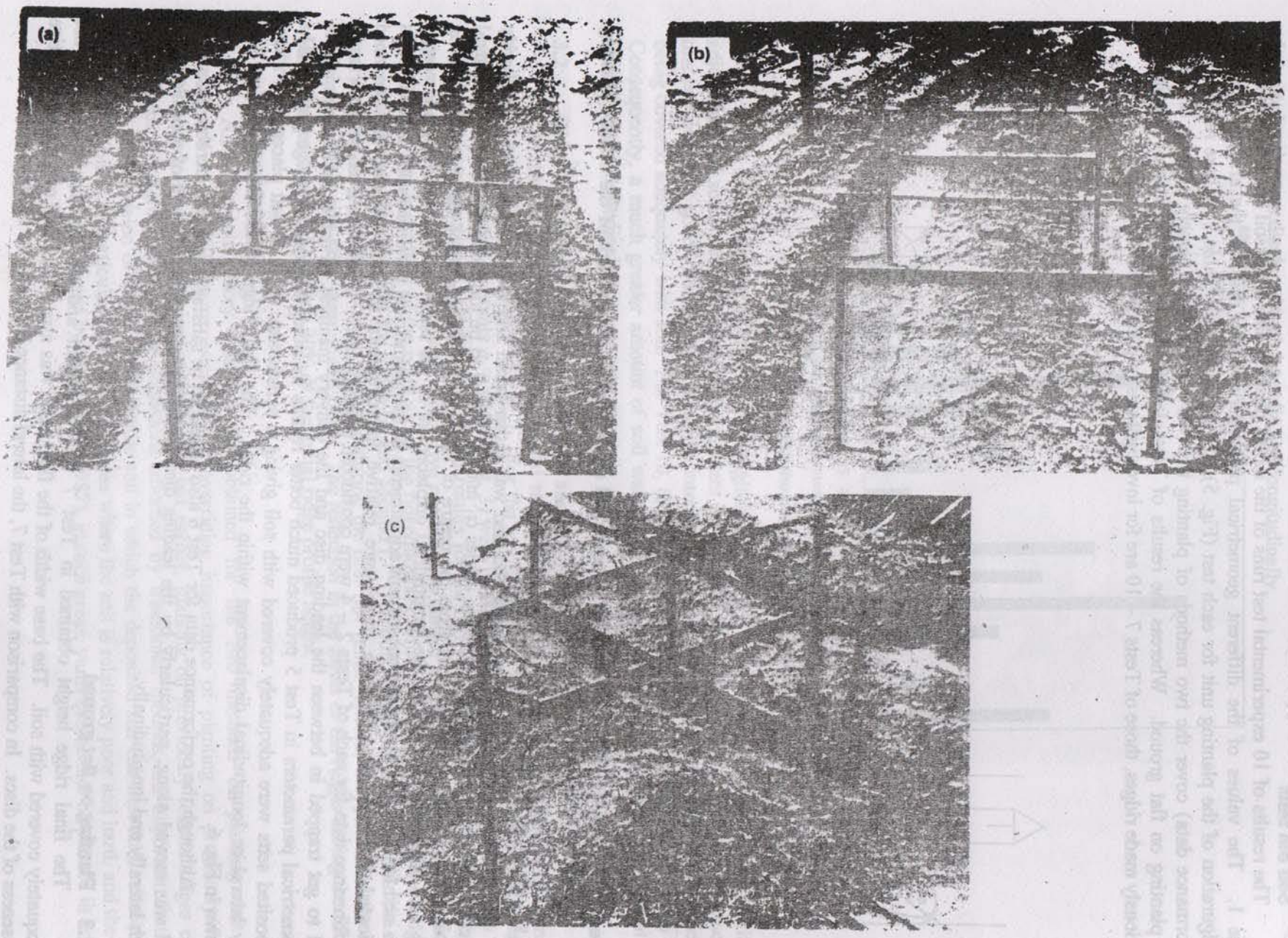

Fig. 4. Profile meters installed across Ridge I (a), Ridge II (b) and Mound I (c) in the field.

3. RESULTS

3.1. Soil bin tests

The results of 10 experimental test runs of the model planting unit in the soil bin are presented in Table 1. The values of the different geometrical parameters, which describe the arrangement and configuration of the planting unit for each test (Fig. 5), are as indicated in Table 1. These results (i.e., performance data) cover the two methods of planting that were investigated, namely planting on ridges and planting on flat ground. Whereas the results of Tests 1 – 6 are for investigations of planting on previously made ridges, those of Tests 7 – 10 are for investigations of planting on flat ground.

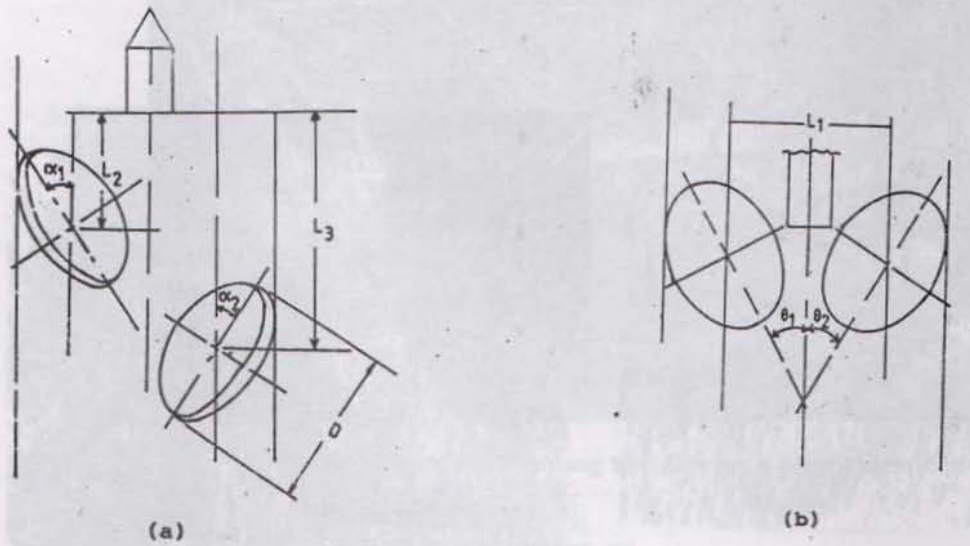

Figure 5: Schematic diagram showing geometrical configuration parameters of the model planting unit. (a) Plan view; (b) Rear view

3.1.1 Planting on previously made ridges

In Test 1, the final ridge height obtained was rather small and the deposited setts were barely covered with soil. Furthermore, the disc angles α_1 and α_2 proved to be too small, resulting in the lateral displacement of the deposited setts from the centre of the ridge. The interval of sett intra-row spacing was also adversely affected by the longitudinal displacement of the setts. The observations and results obtained for Test 1 informed the subsequent adjustments of the geometrical parameters for Tests 2 – 4 as indicated in Table 1. Although there were relative improvements in some aspects, the combined performance data for each of Tests 2 – 4 were considered unsatisfactory. There was a tendency for some soil to get trapped in between the leading disc and the delivery manifold. Further adjustments of the geometrical parameters in Test 5 produced much better results including a good final ridge profile. The deposited setts were adequately covered with soil giving a satisfactory depth of sett placement without any lateral or longitudinal displacement within the ridge. The final ridge profile formed in Test 5 is shown in Fig. 6.

Although the performance data for Test 6 also appear to be satisfactory, a considerable amount of soil was moved along, particularly by the leading disc. This led to the displacement of deposited setts both laterally and longitudinally.

3.1.2 Planting on flat ground

The final ridge height obtained in Test 7 was too small and the deposited setts were not adequately covered with soil. The base width of the final ridge was also quite small owing to the relative closeness of the discs. In comparison with Test 7, the lateral distance between disc centres (L_1) was

increased in Test 8. The disc angles α_1 and α_2 were also increased while the tilt angles θ_1 and θ_2 were decreased. Although there was a general improvement in the performance data, sett placement was still irregular. A large mass of soil was trapped between the leading disc and the delivery manifold indicating that the longitudinal distance between them (L_2) was too small. As the trapped soil was carried along, the deposited setts were displaced both laterally and longitudinally.

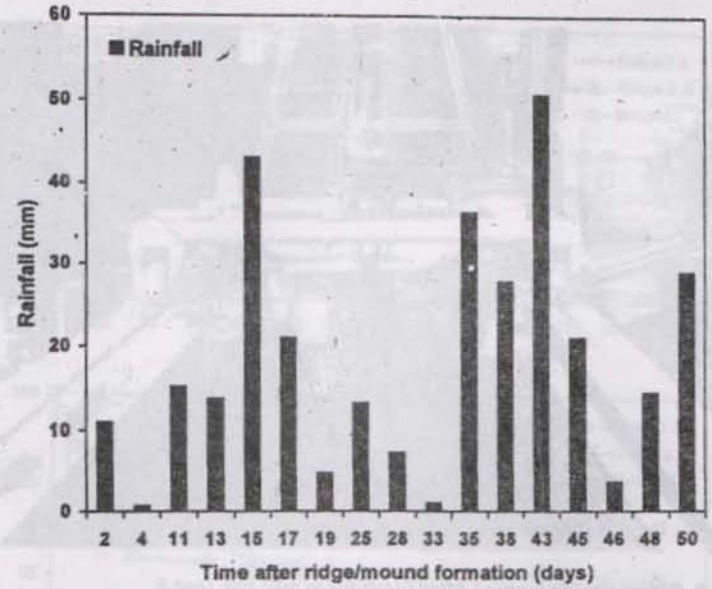

Fig. 7. Rainfall pattern spanning the period of field experimentation

Prior to the conduct of Test 9, the longitudinal distance L_2 was increased along with additional adjustments of some other geometrical parameters as indicated in Table 1. The ridge profile formed for this test was very good. Furthermore, both the interval and placement of setts were quite regular, the setts being covered adequately with soil. For Test 10, the disc angles – particularly α_2 – proved to be too wide. Consequently, a much greater amount of soil was moved by the discs leading to sett displacement both laterally and longitudinally.

3.2 Ridge and mound profile changes with successive rains

The amount and distribution of natural rainfall, during the period of field experimentation with the mound and ridges, are shown in Fig. 7. For the mound and two ridge types investigated, changes in profile height, measured at points *a*, *c* and *e* (Fig. 3) were plotted against cumulative rainfall in Figs. 8(a), 8(b) and 8(c) respectively. Comparison of the results for the different ridges and mound shows that the general trend of profile change with cumulative rainfall was similar at the different points. However, it can be seen that regardless of the point along the ridge/mound profile, the changes recorded for Ridge IIA were consistently smaller than for Ridge IA and Mound I. The bulk of the soil loss (i.e., from the ridges and mound) due to rainfall erosion occurred during the first few rains. Indeed, it appears that the ridges attained a stable size after these initial rains. The reduction in the levels of the ridges during the first few rains ranges between 12.25 and 20% of the initial ridge profile height.

4. DISCUSSION

Although satisfactory results were obtained for the two methods of planting that were investigated in the soil bin experiments, the overriding importance of planting on previously formed ridges cannot be overemphasized. As pointed out earlier, planting on previously formed ridges closely simulates the agronomic planting conditions afforded by traditional mounds, an important feature of which is the provision of ample, loose, fertile soil in which the deposited sett can nest and, subsequently, develop. This is of particular importance in areas where the soil is relatively poor and hard, and the water table is high. As corroborated by Hahn *et al.* (1987), in such areas, yams can neither be planted in holes

nor on flat ground and the only viable option for mechanized yam production is the method of planting on previously formed ridges.

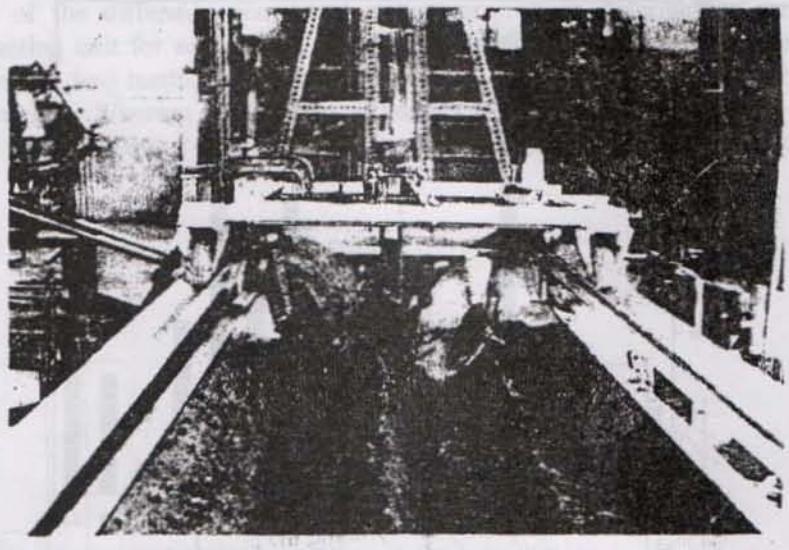

Fig. 6 Ridge profile formed after planting in soil bin Test 5

As mentioned in the preceding section, the bulk of soil loss from the ridges and mound due to rainfall erosion occurred during the first few rains. Indeed, a close examination of Figs. 8 (a) – (c) clearly shows that by the fifth (sometimes fourth) successive rainfall, about 90% of the total ridge/mound profile change recorded at the end of the period of field experimentation had already occurred. Thereafter, ridge and mound profiles seemed to stabilize. This general trend suggests that, apart from the erosion of soil, the initial rains had a two-fold effect on the ridges. Firstly, the impact of the initial raindrops caused some soil compaction. Secondly, the absorption of moisture by the soil resulted in the development of stronger inter-aggregate bonds (cohesion) within the soil. The increased resistance of the ridge/mound to further soil erosion by subsequent rainfall would most likely be accounted for by this two-fold effect.

The investigation of planting on ridges carried out in the soil bin showed that a satisfactory depth of sett placement would fall within the range 0.32 – 0.34D. However, a depth of 0.38D is recommended for sett placement in the field. The increase in the recommended depth is informed by the need to take into account ridge profile changes expected to occur during the first few rains. The greater resistance of Ridge IIA to soil erosion, than those of Ridge IA and Mound I respectively, confirms the soil firming effect of the cylindrical rollers. Hence, the use of cylindrical rollers in the field is highly recommended as a means of further minimizing soil loss from ridges during the first few rains after planting.

5. CONCLUSIONS

The results of soil bin experiments in the present work show that planting on previously made ridges is a feasible and promising mechanization method which simulates the traditional practice of planting yam setts on hand-made mounds. Experiments with the model planting unit further provide useful quantitative and qualitative information, which will serve as a guide for the development and operation of the prototype yam sett planter on the field. In particular, satisfactory results of sett placement and final ridge profile were obtained at a planting speed of 2.7 km/h and for a planting unit configuration featuring a lateral distance of about 1.24D between disc centres, a longitudinal distance of about 0.92D between the leading disc and the delivery manifold, disc angles of about 35°, tilt angles in the range 18° – 23° and a disc penetration depth of about 0.27D. This planting unit configuration

produced a satisfactory depth of sett placement within the range 0.32 – 0.34D. However, to simulate traditional agronomic planting conditions whilst taking into consideration ridge profile changes expected to occur during the first few rains, a depth of 0.38D is recommended for sett placement within ridges in the field. Cylindrical rollers, arranged to trail the planting unit, were found useful as an attachment for planting in the field to enhance the resistance of the ridge to rainfall erosion.

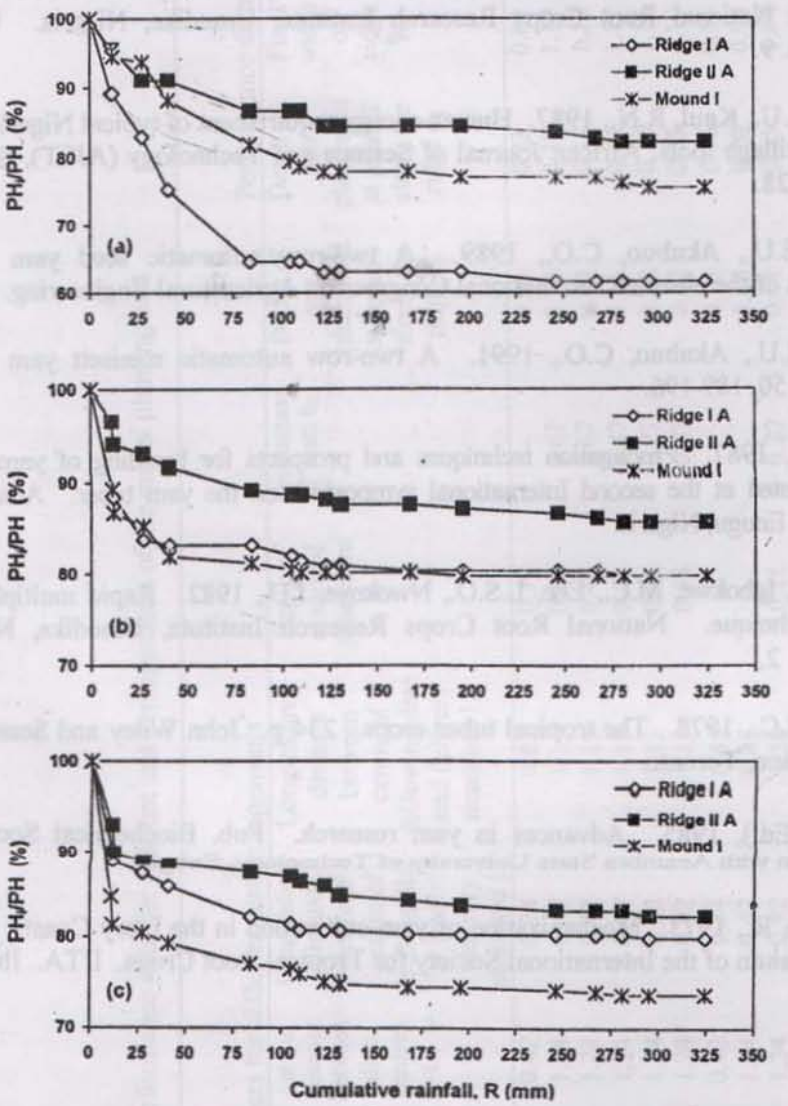

Fig. 8. Changes in profile height plotted against cumulative rainfall for a mound and different ridges at profile meter point *a* (a), profile meter point *c* (b) and profile meter point *e* (c).

REFERENCES

Coursey, D.G., 1983. Yams. Chapter 15 in "Handbook of Tropical Foods". Edited by H.T. Chan, Jr. Marcel Dekker Inc., New York and Basel.

Degras, L., 1993. The yam. A tropical root crop. 408 p. The Macmillan Press Ltd., London, Basingstoke.

Hahn, S.K., Osiru, D.S.O., Akoroda, M.O., Otoo, J.A., 1987. Yam production and its future prospects. Outlook on Agriculture, Vol. 16 No. 3, pp. 105 – 110. Pergamon Journals Ltd., Great Britain.

Iwueke, C.C., Mbata, E.N., Okereke, H.E., 1983. Rapid multiplication of seed yam by minisett technique. National Root Crops Research Institute, Umudike, Nigeria. Umudike Advisory Bulletin No. 9.

Nwuba, E.I.U., Kaul, R.N., 1987. Human energy requirement of typical Nigerian traditional tillage tools. African Journal of Science and Technology (AJST), Series A Vol. 6 No. 1, pp. 20 – 28.

Odigboh, E.U., Akubuo, C.O., 1989. A two-row automatic seed yam planter prototype. Proceedings of the eleventh International Congress on Agricultural Engineering. Dublin, Ireland.

Odigboh, E.U., Akubuo, C.O., 1991. A two-row automatic minisett yam planter. J. Agric. Engng. Res. 50, 189-196.

Okoli, O.O., 1987. Propagation techniques and prospects for breeding of yams (Dioscorea spp.). Paper presented at the second International symposium on the yam tuber. Anambra University of Technology, Enugu, Nigeria.

Okoli, O.O., Igbokwe, M.C., Ene, L.S.O., Nwokoye, J.U., 1982. Rapid multiplication of yam by minisett technique. National Root Crops Research Institute, Umudike, Nigeria. Research Bulletin No. 2.

Onwueme, I.C., 1978. The tropical tuber crops. 234 p. John Wiley and Sons, Chichester, New York, Brisbane, Toronto.

Osuji, G. (Ed.), 1985. Advances in yam research. Pub. Biochemical Society of Nigeria in collaboration with Anambra State University of Technology, Enugu.

Vandevenne, R., 1973. Mechanization of yam cultivation in the Ivory Coast. Proceedings of the third symposium of the International Society for Tropical Root Crops. IITA. Ibadan, Nigeria.

Table 1
Geometrical parameters and some associated performance data for different test arrangements of the model planting unit

Test	Geometrical parameters for different test arrangements*												Performance data*			
	Initial width of ridge W_i	Initial height of ridge H_i	Left disc angle α_1 (°)	Right disc angle α_2 (°)	Right tilt angle (°)	Left tilt angle θ_1 (°)	Right tilt angle θ_2 (°)	Lateral distance between disc centres L_1	Longitudinal distance between centre of leading disc and delivery manifold L_2	Longitudinal distance between centre of following disc and delivery manifold L_3	Depth of manifold penetration h_1	Penetration of discs h_2	Depth of sett placement at point 1 along the ridge d_1	Depth of sett placement at point 2 along the ridge d_2	Final width of ridge W_f	Final height of ridge H_f
1	0.96	0.57	27	28	8	29	30	0.42	0.34	0.85	0.39	-	0.15	0.23	0.62	0.36
2	0.96	0.51	18	31	1	23	23	1.24	0.47	1.15	0.48	0.67	0.30	0.33	1.10	0.60
3	0.96	0.51	24	31	1	23	23	1.24	0.47	1.15	0.48	0.67	0.30	0.35	1.18	0.59
4	0.96	0.51	31	31	1	23	23	1.24	0.47	1.15	0.48	0.47	0.31	0.33	1.12	0.56
5	0.96	0.51	35	31	1	23	23	1.24	0.92	1.15	0.48	0.27	0.32	0.34	1.15	0.56
6	0.96	0.51	40	31	1	23	23	1.24	0.92	1.15	0.48	0.27	0.32	0.35	1.19	0.57
7	-	-	27	28	8	29	30	0.42	0.34	0.85	-	-	0.15	0.16	0.58	0.30
8	-	-	31	31	1	23	23	1.24	0.47	0.85	-	-	0.15	0.20	0.94	0.39
9	-	-	35	35	5	22	18	1.24	0.92	1.38	0.11	0.27	0.11	0.15	1.04	0.43
10	-	-	42	54	4	22	21	1.24	0.92	1.38	0.11	0.27	0.12	0.14	1.02	0.45

* All linear measurements are expressed as fractions of the disc diameter D (= 300 mm)

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EXPERIMENTAL EVALUATION OF INFILTRATION EQUATIONS FOR NSUKKA SOIL

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ABSTRACT

Four infiltration equations (Kostiakov, Horton, Green and Ampt and Philip) adapted to ponded infiltration condition were evaluated for their ability to predict infiltration into the predominant soil in the Nsukka agricultural zone of Enugu State. The double ring infiltrometer technique was used to generate infiltration data. The prediction of infiltration by the infiltration equations reflect fair to good agreement with observed values while the overall performance rating shows the Kostiakov equation performing best, followed, in order of performance, by the Philip, Horton and Green and Ampt equations. The study, therefore, is a contribution to the gradual build-up of the evaluated parameters of existing infiltration equations that can be used in the study area.

KEYWORDS

Experimental, Evaluation, Infiltration Equations

INTRODUCTION AND THEORY

Many situations arise in hydrology where it is desirable to evaluate water infiltration into the soil under either ponded or rainfall condition. It is, for example, the infiltrability of the soil that determines for a given storm, the amount and time distribution of rainfall excess that is available for runoff and surface storage. The same soil related factors that control infiltration also govern soil water movement and distribution during and after infiltration process. Watershed modeling, prediction of surface runoff and design of irrigation systems are some other situations that require accurate evaluation of the infiltration component of the hydrologic cycle.

Many studies have been carried out in attempts to establish concepts that adequately describe the infiltration process in the field. Such studies have yielded various infiltration equations and models. Equations 1 to 6 give some of these equations:

Kostiakov (1932) Equation

$$f_t = at^b \quad (1)$$

Where a, b are constants ($0 < b < 1$) which cannot be predicted in advance but are usually fitted from test data.

Horton (1940) Equation:

$$f_t = f_c + (f_o - f_c)e^{-kt} \quad (2)$$

Where k is a constant and depends on soil type and initial moisture content.

Green and Ampt (1911) Equation:

$$f_t = K_s \left(1 + \frac{nS}{F_t}\right) \quad (3)$$

Where n is the initial moisture deficit, $(\theta_s - \theta_j)$.

Philip (1957) Equation:

$$f_t = st^{1/2} + At \quad (4)$$

Where s and A are constants depending on the soil and its initial moisture content.

Holtan (1961) Equation

$$f_t = f_c + a_I (S_p - F_t)n_1 \quad (5)$$

Where a_i (0.25 –0.80) is a constant and n_1 another constant dependent on soil type. a_1 and n_1 can be obtained as the intercept and slope respectively of the log-log plot of the quantity, $(f_t - f_c)$ vs $(S_p - F_t)$.

Mein and Larson (1971) Equation:

$$F_s = \frac{Sav(IMD)}{I/K_s - 1} \quad (6a)$$

$$f_t = K_S\left[1 + \frac{Sav\ (IMD)}{F_t}\right] \quad (6b)$$

In equation 1-6;

F_t - Accumulated infiltration value to time t, expressed as depth (cm)
t - time from onset of infiltration (min)
f_t - infiltration rate at time, t (cm/hr)
f_c - final or equilibrium infiltration rate (cm/hr)
f_o - initial infiltration rate (cm/hr)
K_s - conductivity at the wetted zone which is equal to saturated hydraulic conductivity (cm/hr)
S - capillary suction at the wetting front (cm)
θ_s - saturated moisture content (% vol/vol)
θ_i - initial moisture content (% vol / vol)
S_p - storage potential of the soil above the control depth, which is expressed as depth (cm)
F_s - infiltration volume to the time of surface saturation which is expressed as depth (cm)
S_{av} - average capillary suction at the wetting front obtained from the capillary suction – conductivity (S-k) relationship for the soil (cm)
IMD - Initial moisture deficit = porosity minus initial moisture content (% vol/vol)
I - rainfall intensity (cm/hr).

The Kostiakov, Horton and Holtan equations (Eqns. 1, 2, 5) are empirical algebraic equations while the Green and Ampt, Philip and Mein and Larson equations (Eqns. 3, 4, 6) are theoretically derived.

Equation 1 gives the simple form of Kostiakov infiltration equation, which has no provision for predicting when runoff will begin under a rainfall input condition. The simplicity has encouraged the use of this equation in flood irrigation studies (Fok, 1967). The characteristics of Eqn. 1 are that the initial value of the infiltration rate is infinite and that as the time increases, the infiltration rate approaches zero instead of a constant (non-zero) value as has been observed practically (Mbagwu, 1997). The Horton equation (Eqn. 2) is the most widely known infiltration expression whose best feature is its simplicity and good fit to experimental data. It is adapted to ponded condition since it cannot be used to predict rainfall infiltration prior to surface ponding (Mein and Larson, 1971). A more recent infiltration equation is the Holtan expression (Eqn.5) which is well suited for inclusion in a watershed model because it links infiltration rate to the soil moisture level and is not directly time dependent. However, the major difficulty of the Holtan model is specifying the control depth since it (control depth) has a large influence on the prediction of infiltration.

The Green and Ampt equation (Eqn.3) assumes that the soil surface is covered by a pool of water (ponded condition) but whose depth can be neglected. Equation 4 is an adaptation of Philip's solution of the partial differential equation of soil moisture flow for a homogeneous soil with a uniform initial moisture content and an excess water supply at the surface (ponded condition). The form of the equation is convenient and the constants s and A which can be predicted in advance or obtained by fitting the equation to field data, have been referred to as the sorptivity and transmissivity respectively. The sorptivity term (with dimensions of $LT^{-\frac{1}{2}}$) reflects the soil ability to absorb water by matric forces during the initial stages of the infiltration process (Mgagwu, 1997), while the transmissivity term (with dimensions of LT^{-1}) reflects the ability of the soil to transmit water under ponded conditions (Philips, 1957b). Mbagwu, 1997 showed that the soil saturated hydraulic conductivity is linearly correlated with

Philip's A (transmissivity) and has the same relationship with Kostiakov's "a" parameter. Consequently, Mbagwu, 1997 suggested that this parameter depicts the ability of the soil to transmit water under ponded condition just as the "A" term in the Philip model was defined above. Skaggs et al (1969) have experimentally evaluated the infiltration equations due to Green and Ampt (Eqn 3), Horton (Eqn. 2), Philip (Eqn. 4) and Holtan, England and Shanholtz (Holtan et al, 1967) on the basis of large-plot field data and obtained numerical values for the parameters in the four equations for several different soils at varying initial moisture contents and surface conditions. Mbagwu (1997), in a detailed study on the soil physical properties influencing the fitting parameters in the Philip and Kostiakov infiltration equations (Eqns 4 and 1 respectively) has established values of the parameters of the two equations as well as how these parameters correlate with the soil physical properties for eighteen sites with different land use histories on the University of Nigeria, Nsukka Teaching and Research Farm which is the general area of the site of the present study.

This study evaluates four infiltration equations (Kostiakov, Horton, Green and Ampt and Philip) under field condition on the predominant soil in the Nsukka agricultural zone of Enugu State. The specific objectives of the study include:

- Experimental evaluation of the parameters of the four infiltration equations under study.
- Experimental verification of the infiltration predicted by the infiltration equations and
- Comparison of the infiltration predicted by the infiltration equations.

MATERIALS AND METHOD

The soil in the experimental site (the Department of Agricultural Engineering Research Farm) is deep, porous and ferrallitic and belongs to the group broadly classified as ultisols and is the predominant soil in the Nsukka agricultural zone of Enugu State. The site has been cultivated to Nsukka Yellow Pepper (*Capsicum annum L*). for the previous two years.

Infiltration data under ponded condition were generated from test plots. Three plots, each 100cm x 100cm were selected for the infiltration runs using double ring infiltrometer. Before each infiltration run, soil samples were taken from the top 15 cm of the plots for laboratory determination of the physical characteristics of the soil such as initial moisture content, bulk density and porosity. At least two infiltration runs were carried out on each plot with each run lasting for about two hours. The saturated hydraulic conductivity, K_s. and the capillary suction at the wetting front, S were not determined for this study but adapted from an earlier research work (Idike and Ejieji, 1993) on the same site. In this earlier study, S was evaluated by applying the method for determining unsaturated conductivity from moisture retention data proposed by Campbell (1974), while Ks was determined by the constant head permeameter technique.

The parameters of the infiltration equations studied were determined either from the infiltration runs or by fitting using the generated infiltration data or adapted from other related studies carried out on the same site. Only a part of the data generated in the study was used for evaluating the equation parameters while the rest was used for evaluating the performance of the equations in predicting infiltration rates.

RESULTS AND DISCUSSION

Laboratory analyses of soil samples taken from the experimental test plots show that the soil is sandy loam and has the following physical characteristics (Okolo, 1994);

Field capacity	-	21.0%
Permanent wilting point	-	13.3%
Total available soil moisture	-	7.7%
Bulk density	-	1.62 gm/cm^2

All soil moisture characteristics were determined on dry basis.

Table 1 presents the infiltration data generated in the study using the double ring infiltrometer technique. Table 2 presents the infiltration rates with time as predicted by the infiltration equations studies.

Although the generated infiltration data (Table 1) reflect the infiltration pattern expected under ponded condition, there are few cases of unexpected higher infiltration rates with time as well as unexpected drastic drops in observed infiltration rates with time. For example, the average infiltration rate at the 30th minute was 61.68 cm/hr and at the 35th minute, 62.16 cm/hr; at the 50th minute, 38.58cm/hr and at the 60th minute, 39.78 cm/hr while the average infiltration rate of 61.56cm/hr at the 40th minute drastically dropped to 38.58cm ten (10) minutes later.

Table 1 Generated Infiltration Data (Average values of all runs)

Time (min).	Infiltration Depth (cm)	Cumulative Infiltration Depth (cm)	Infiltration rate f_p cm/hr
0	0	0	0
1	2.0	2.0	120.0
2	2.04	4.04	122.40
3	1.86	5.90	111.60
4	1.86	7.76	111.60
5	1.77	9.53	106.20
6	1.75	11.28	105.00
7	1.69	12.97	101.40
8	1.66	14.63	99.60
9	1.56	16.19	93.60
10	1.29	17.48	77.40
15	5.58	23.06	66.94
20	5.53	28.59	66.36
25	5.51	34.10	66.12
30	5.14	39.24	61.68
35	5.18	44.42	62.16
40	5.13	49.55	61.56
50	6.43	55.98	38.58
60	6.63	62.61	39.78
70	6.12	68.73	36.72
80	6.16	74.89	36.96
90	6.10	80.99	36.60
100	6.16	87.15	36.96
110	6.16	93.31	36.96
120	6.16	99.47	36.96

Higher infiltration rates with time are unusual and may be explained by possible presence of holes created by burrowing rodents as observed by Idike et al (1980), while a logical explanation for the drastic drop in infiltration rate could be the presence of hard pan within the soil depth; a condition that is possible since the study site had been under plough cultivation every year for quite a long time, either for crop production or for farm operations demonstration exercises.

The predicted infiltration rates by the infiltration equations (Table 2) suggest fair to good agreement with the observed values while Table 3 reveals more details on the performance of the infiltration equations. All the infiltration equations under-predicted infiltration rates during the early stages (0 – 40 minutes) of the runs, with the Kostiakov equation performing best, followed in order of good performance, by the Philip, Green and Ampt and Horton equations. During the latter stages (50 – 120 minutes) of the runs, both the Kostiakov and Green and Ampt equations overpredicted the infiltration rates at all times while the Horton and Philip equations gave much more accurate predictions. During these latter stages of the run, the Horton equation performed best, followed, in order of good performance by the Philip, Kostiakov and Green and Ampt equations. The overall performance rating for the four infiltration equations starting with the best performance is Kostiakov, Philip, Horton and Green and Ampt equations.

Table 2 Observed and predicted infiltration rates

Time (min).	Observed Infiltration Rate (cm/hr)	Predicted Infiltration Rates (cm/hr)			
		Kostiakov	Horton	Green & Ampt	Philip
10	77.40	70.25	75.03	65.44	76.79
15	66.94	64.79	61.77	58.78	66.78
20	66.36	61.17	53.01	54.66	60.62
25	*66.12*	*58.53*	*47.34*	*51.84*	*56.23*
30	61.68	56.47	43.66	49.80	52.65
35	62.16	54.76	41.30	48.29	49.93
40	61.56	53.38	39.76	46.98	49.38
50	38.58	51.42	38.12	45.94	44.96
60	39.78	50.25	37.43	44.43	42.87
70	36.72	49.11	37.15	44.42	41.33
80	36.92	41.42	37.02	43.88	39.41
90	36.60	39.95	36.97	43.38	37.99
100	36.69	39.00	36.94	42.97	35.57
110	36.69	37.79	36.94	42.59	35.46
120	36.69	37.54	36.94	42.69	35.39

Table 3 Departures in predictions by the Infiltration Equations

Time (min).	Observed Values (cm/hr)	Departures in Predictions (cm/hr)			
		Kostyakov	Horton	Green & Ampt	Philip
10	77.40	-7.15	-2.37	-11.81	-0.16
15	66.94	-2.15	-5.17	-8.16	-0.16
20	66.36	-5.43	-13.35	-11.70	-5.74
25	66.12	-7.59	-18.78	-14.28	-9.89
30	61.68	-5.20	-18.02	-11.88	-9.03
35	62.16	-7.4	-20.86	-13.87	-12.78
40	61.56	-8.18	-21.80	-14.58	-12.18
50	38.58	12.85	-0.46	7.36	6.38
60	39.78	10.47	-2.35	4.65	3.09
70	36.72	12.39	0.43	7.70	4.61
80	36.92	4.46	0.06	6.92	2.45
90	36.60	3.35	0.37	6.78	1.39
100	36.69	2.04	-0.01	6.01	-0.39
110	36.69	0.83	-0.02	5.63	-1.50
120	36.69	0.58	-0.02	5.73	-1.57

Note: - ve refers to underprediction
+ ve refers to overprediction

Table 4 shows the parameters of the infiltration equations studied either as evaluated using data generated in this study or as adapted for the study from other relevant studies carried out on the same site. Mbagwu's (1997) evaluation of the parameters in the Kostiakov and Philip infiltration equations for eighteen sites with different land use histories on the University of Nigeria, Nsukka Teaching and Research farm (which is the general area of the site of the present study) shows that the evaluated corresponding parameters of this study are within the ranges obtained in the former study (table 4). This is a reasonably favourable measure of the confidence in the parameters of the other equations evaluated in this study. Moreover, the general performance of the infiltration equations in predicting infiltration in this

study (as discussed earlier) tends to suggest that the evaluated / adapted values of the parameters of these equation are appropriate.

Table 4 Infiltration equation parameters determined / evaluated or adapted for the study

Infiltration Equation Parameter	Values determined / evaluated or adapted	Ranges of values evaluated by Mbagwu (1997)
Kostiakov		
a	115.0 cm/hr (2.0cm/min)	0.60 – 26.0 cm /min
b	0.28	0.654 – 0.925
Horton		
f_c	0.35 40cm/hr (0.67cm/min)	
Green and Ampt		
K_s	31.5 cm/hr	
n	11%	
S	2.50cm (Idike & Ejieji, 1993)	
Philip		
s	86.6cm/hr ½ (11.18 cm/ min ½)	3.76 – 18.6 cm/min ½
A	4.14cm/hr (0.07cm / min)	0.04 – 1.02 cm / min

CONCLUSION

A field evaluation of four infiltration equations (Kostiakov, Horton, Green and Ampt, and Philip) was carried out on the predominant soil in the Nsukka agricultural zone of Enugu state. The field experiment generated acceptable infiltration data which were used in evaluating the parameters of the infiltration equations. The prediction of infiltration rates by the infiltration equations reflect fair to good agreement with observed values. The performance rating of the infiltration equations shows the Kostiakov equation performing best overall, followed, in the order of performance, by Philip, Horton and Green and Ampt equations

The fact that the value of the evaluated parameters in the Kostiakov and Philip equations agree favourably with the values obtained in another work in the general area of the study (Mbagwu, 1997) is a reasonably favourable measure of the confidence in the parameters of the equations evaluated in this study. Consequently, the study has contributed to the gradual build-up of evaluated parameters of existing infiltration equations that can be used in the study area.

REFERENCES

Campbell, G. S. (1974). A simple method of determining unsaturated conductivity from moisture retention data. Soil science 117 (6); 311 – 314.

Fok, Y. S. (1967). Infiltration equation in exponential forms. Trans. ASCE 93 (IR4) 125 –136.

Green, W. H. and G. A. Ampt (1911). Studies on Soil Physics: (i) The flow of air and water through soils; J. Agric. Sci. A: 1 - 24.

Holtan, H. N. (1961). A concept for Infiltration Estimates in Watershed Engineering. ARS Paper 41 –51.

Holtan, H. N; C. B. England and V. O. Shanholtz, (1967). Concept of hydrologic soil grouping. Trans. ASAE 10(3); 407 –410.

Horton, R. E. (1940). An approach towards a Physical Interpretation of Infiltration Capacity. Soil Sci. Soc. Amer. Proc. 5, 339 – 417.

Idike, F. I. and C. J. Ejieji (1993). Applicability of selected methods of estimating hydraulic properties of a tropical soil. Soil Technology, (6) 299 – 309.

Idike, F. I; C. L. Larson, D. C. Slack and R. A Young (1980). Experimental evaluation of two infiltration models. Trans. ASAE 23(a), 1428 – 1433.

Kostiakov, A. N. (1932). On the dynamics of the coefficient of water – percolation in soils and on the necessity for studying it from a dynamic point of view for purposes of amelioration. Trans. 6th Com. Intern. Soc. Solid Sci. Russian Part, A: 17 –21

Mbagwu, J. S. C. (1997) Soil physical properties influencing the fitting parameters in Philip and Kostiakov infiltration models. Discovery and Innovation 9(3/4) 1997 pp 179 – 187

Mein, R. G. and C. L. Larson (1971). Modelling the Infiltration Component of the Rainfall-Runoff Process. WRRC, University of Minnesota Graduate School Bull. 43, 77 pages .

Okolo, C. A. (1994) Experimental evaluation of infiltration equations for Nsukka soil Unpublished B. Eng Project report; Dept of Agricultural Engineering, University of Nigeria, Nsukka 44pp.

Philip, J. R. (1957). The theory of infiltration I. The Infiltration Equation and its solutions. Soil Sci. 83: 345 – 357

Philip, J. R. (195 7b). The theory of infiltraion. 4. Sorptivity and algebraic infiltration. Soil Sci; 84,257-264.

Skaggs; R. W; L. E. Huggins; E. J. Monke and G. R. Foster (1969). Experimental evaluation of infiltration equations Trans. ASAE 12(6); 822 – 828.

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RELATION OF FIVE CONTINUOUS TILLAGE PRACTICES TO MAIZE (*Zea mays* L.) PRODUCTION ON ULTIC HAPLUSTALF

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ABSTRACT

This paper investigates the effect of tillage practices on seedling emergence, growth and yield of maize on ultic haplustalf. Five tillage practices: arara ploughing followed by ziz-zag harrowing and arara ridging (T1), emcot ploughing followed by ziz- zag harrowing and emcot ridging (T2), mouldboard ploughing followed by disc harrowing and disc ridging (T3), disc ploughing followed by disc harrowing and disc ridging (T4) and manual ridging (T5) were studied. Good soil tilth of medium aggregate seedbeds, high tillage depth, accelerated emergence of seedlings and increased crop yield were obtained in T4. Data from three levels of soil moisture content (17, 20 and 26%, w/w) showed that soil penetration resistance and bulk density were influenced by moisture content with lower bulk density in the topsoil than in the subsoil. An increase in soil moisture content from 15.72 to 24.70%, w/w, increased maize grain yield from 2.77 to 5.60 t ha^{-1}. High soil strength resulted in low crop yield due to restriction of soil moisture and compaction created by wheel traffic during tillage. Tillage practices significantly affected ($P \leq 0.01$) the seed and seedling mortality, emergence rate index, leaf area index and maize grain yield. Good soil tilth and high crop yield was obtained in T4 which is considered most appropriate for adoption for maize production on the investigated soil.

KRYWORDS
Intensive cultivation; soil strength; continuous farming; monoculture.

1.0 INTRODUCTION

Continuous farming under monoculture is the predominant form of crop production in northern Nigeria with intensive cultivation using large tractors and equipment for tillage. This type of operation in some agricultural soils leads to a deterioration in soil structure and other physical properties of the soil. Previous researchers (Gerard et al., 1982; Box and Langdale, 1984; Idel et al., 1984; Schuler and Lowery, 1984; Yusuf, 1996 and Yusuf, 2001) reported that as soil bulk density and soil strength increased, seedling emergence, crop growth and yield decreased as a result of high axle loads. Even though higher bulk densities and soil strength persisted in the soil profile several years after compactive treatments had been applied, crop yield reduction after a corresponding length of time had nearly disappeared (Hakansson, 1982; Gameda et al., 1984). This observation has led to speculation that additional factors may be responsible for crop yield.

More detailed information is required in order to evaluate the significance of tillage systems on crop yield, and eventually, to optimise soil management and crop yield. Hence, the objective of this study was to investigate the influence of five continuous tillage systems on seedling emergence, growth and grain yield of maize.

2.0 MATERIALS AND METHODS

2.1 Site

Field trials were conducted at Samaru (11°11'N, 07°38'E and 685m above sea level) in Kaduna State, Nigeria. Samaru soils have been classified as Ultic haplustalf (Valette and Ibanga, 1984) and such soil is freely draining with permeability of 0.8 to 1.5 cm/ hr within the cultivated soil layer. However, the soil is weakly bufferred and has been reported to be low in cation exchange capacity (CEC), organic matter and nitrogen (Heathcote and Stockinger, 1970).

2.2 Soil Profile

The soil profile is characterized generally by a sandy surface horizon underlying a horizon of clay accumulation, with a weak sub-angular blocky structure and a reddish-brown to a grayish brown colour (Pugh and King, 1952). The pedon belongs to the order of ferrugineous tropical soils formed from transported fine-grained loam material on broad gentle slopes in an undulating topography.

2.3 Tillage, Planting and Nitrogen Treatments

The five tillage practicess investigated were: arara ploughing followed by zig-zag harrowing and arara ridging (T1), emcot ploughing followed by ziz-zag harrowing and emcot ridging (T2), mouldboard ploughing followed by disc harrowing and mouldboard ridging (T3), disc ploughing followed by disc harrowing and disc ridging (T4) and manual ridging (T5). The planting methods were: manual planting (P1) and mechanical planting (P2) with a single - row animal-drawn planter. The nitrogen rates were: no nitrogen (NO), 40kgNha^{-1} (N1), 80 kgNha^{-1} (N2), and 120 kgNha^{-1} (N3).

2.4 Experimental Design

The treatments were randomly assigned in a 4 x 5 x 2 factorial experiment arranged in a strip-split design with the tillage methods as horizontal treatments, nitrogen rates as vertical treatments, and planting methods as sub-plot treatments in four replications as outlined by Gomez and Gomez (1984).

2.5 Field Operations and Measurements

Soil samples were collected from Ap horizons of the soil and to obtain comparable results, all the soils were sampled before they had been fertilized. This ensured "baseline samples" that were influenced as little as possible by annual fluctuations due to seasonal peaks in nitrogen input. Five replicates of soil cores were collected randomly with rectangular samples (750mm x 115mm) from each plot for soil characteristics, soil moisture and bulk density determinations.

Moisture content of the upper 20cm soil was determined gravimetrically after drying at 105°C for 24 h. Soil bulk density was determined at sowing, using a volume core (15 cores at 50-mm diameter and 30-mm high each) method (Blake and Hartge, 1986). Soil resistance to cone penetrometer pressure was measured in each plot using a reading penetrometer (Anderson et al., 1980) with a 12.8mm diameter and 30° angle of the cone at 0.05m increments to a depth of 0.30m. Some chemical and granulometric characteristics of the soil, determined by standard laboratory methods (Campbell et al., 1978), are presented in Table 1. Details of the weather for the duration of the experiment (1997-1999) are given in Table 2 and Fig. 1. The weather station is about 0.5km north of the field site. Personal data of the test farmers (Table 3) were collected and the physical efficiency index (PEI) was calculated by using the relation described by Johnson et al. (1942) as:

$$PEI = \frac{\text{Duration at operation in seconds}}{\text{2 x sum of pulse counts in recovery}} \times 100 \quad (1)$$

The surface area of each farmer's body was calculated using the equation stated by DuBois and DuBois (1916) as:

$$A = W^{0.425} \times H^{0.725} \times 71.84 \quad (2)$$

where:

A = surface area of body (cm^2);
H = Weight of the body (kg);
H = height of the farmer (cm)

Table 1: Some characteristics of the soil samples (0-30 depth) at Samaru, Nigeria

Chemical Characteristics[a]	Value		
	1997	1998	1999
pH-KCl	5.8	5.2	5.5
pH - (1:1, v/v H_2O)	6.7	6.7	6.8
Available P (ppm)	3.7	5.3	6.0
Organic carbon (%, w/w)	0.5	0.3	0.5
Total Nitrogen (%, w/w)	0.04	0.06	0.09
EC (mm hos/cm at 25^0C)	0.5	0.2	0.2
CEC (meq/100g. soil)	7.7	6.4	5.2
Exch. Cations (meq/100g soil):			
Ca^{2+}	2.53	3.01	2.3
Mg^{2+}	0.80	1.20	0.8
K^+	0.24	0.32	0.20
Na^+	0.18	0.16	0.14
Total exchangeable bases (meq/100g.soil)	3.75	4.69	3.44
Granulometric characteristics[a]:			
Clay, <2μm (%, w/w)	15	17	17
Silt, 2-50μm (%, w/w)	17	17	13
Fine sand, 50-600μm (%, w/w)	30	35	38
Coarse sand, 600μm -2mm (%, w/w)	38	31	32

[a]Each value is a mean of five single measurements.

Table 2: Mean temperatures (May-August and Annual) for the periods 1957-1976, 1977-1996 and 1997-1999 at Samaru, Nigeria.

Period	Mean Temperature (°C)[a]	
	May-August	Annual
1957-1976	29.700 (1.728,5.818)	30.900 (2.860,9.256)
1977-1996	32.400 (2.098,6.475)	31.300 (1.822,5.821)
1997	29.600 (2.892,9.870)	31.200 (2.925,9.375)
1998	29.300 (2.892,9.870)	30.500 (1.951,6.397)
1999	29.200 (1.791,6.134)	30.800 (2.321,7.536)

[a]Values in parenthesis are standard deviation and coefficient of variation in percentages, respectively.
Source: Agro-Meteorological Service Unit, Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria.

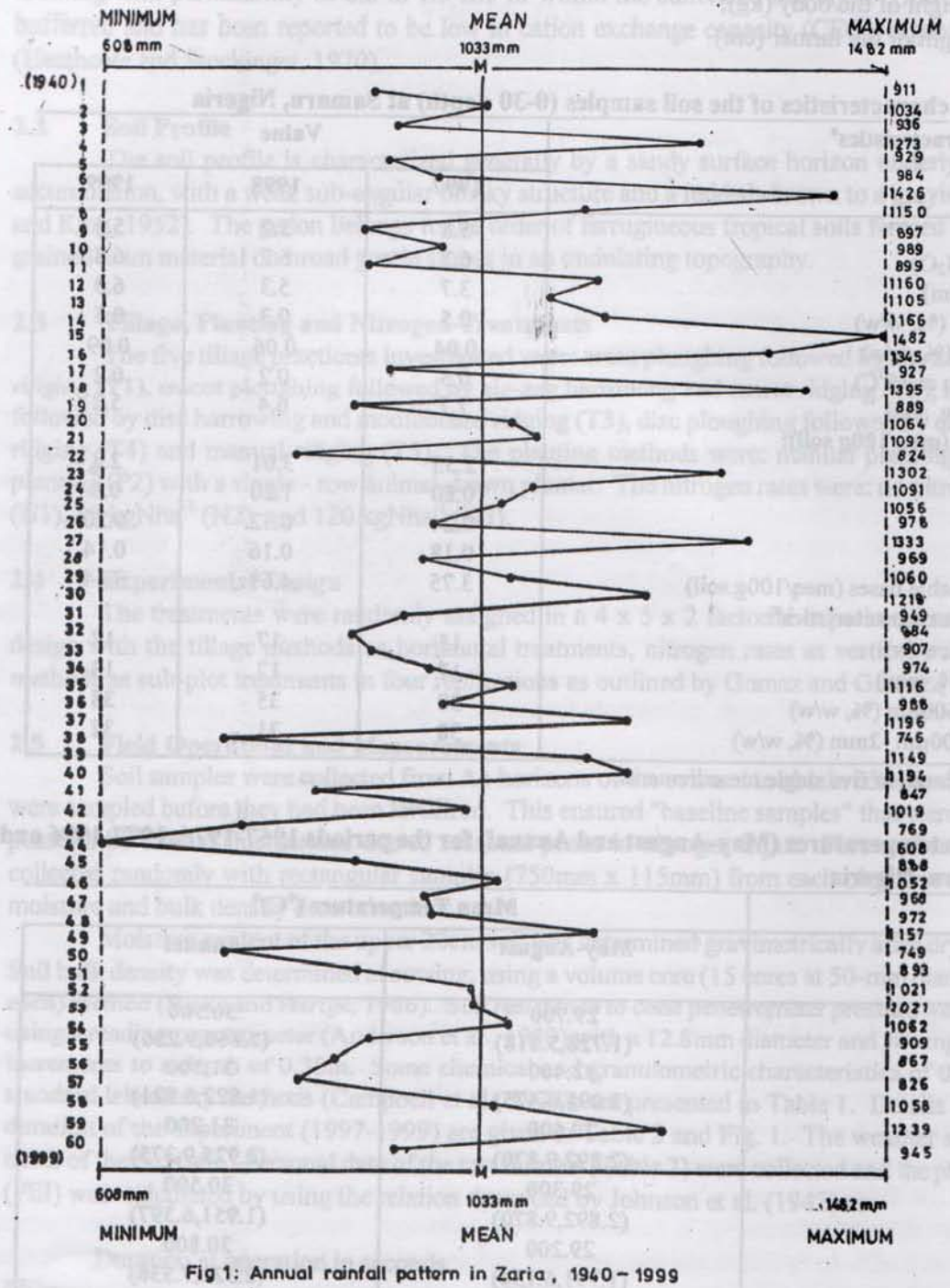

Fig 1: Annual rainfall pattern in Zaria, 1940 – 1999

Source: Agro Meteological Service Unit, Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria.

The manual method of planting "mimicks" the "prehistoric man's method of planting in the absence of any form of mechanical aid. Maize (*Zea mays* L.) of TZSR-W crop variety was used as test crop. After tillage and planting, the soil was dug out and depths of tillage and seed placement were randomly measured with steel rule. The implement combination and farm management carried out were based on the practice followed by the farmers that grew maize around the area investigated.

Table 3: Personal data of subjects used for the field operations during the 1997-1999 cropping seasons at Samaru, Nigeria.

Personal data	Subjects		
	1	2	3
Sex	Male	Male	Male
Age	40	43	38
Height, m	1.6	1.3	1.7
Body weight, kg	65	60	63
Body surface area, m^2	1.7	1.6	1.7
Health condition (subjective)	Good	Good	Good
Occupation	Farming	Farming	Farming
Physical efficiency index (PEI)	62	59	70
Preferred physical activities	bc,r,p,w,d	r,b,d,p	r,p,s

Note: b = bicycling, r = ridging, s = swimming, w = weeding, d = digging, p = planting, bc = bush clearing

Germination of seeds and emergence of seedlings were monitored three times every day (morning, afternoon and evening) after planting and records were maintained on seedling emergence starting on the day of initial emergence and continued until full emergence. Mean emergence data (MED) and emergence rate index (ERI) were calculated directly using the equation of Bilbro and Wanjura (1982) from the emergence counts as follows:

$$MED = N_1t_1 + N_2t_2 + ... + N_nt_n)/(t_1 + t_2 + ...+ t_n) \quad (3)$$

$$ERI = (N_1 + N_2 + ... + N_n)/MED \quad (4)$$

where N_1, N_2, ... N_n are numbers of newly emerged seedlings at times t_1, t_2, ... t_n.

Percentage seed and seedling mortality were obtained from the equation (Joshi, 1987):

$$\text{Percentage seed and seedling mortality} = \frac{100 - UE}{\text{Lab. germination \%}} \quad (5)$$

where:
UE = Ultimate emergence (the maximum number of seedlings that emerged during the experiment). Leaf area (LA) of the individual leave was estimated by the equation given by Saxena and Singh (1965) as:

$$LA = 0.75 \times \text{length} \times \text{breadth} \quad (6)$$

Leaf area index (LAI) was calculated as (Watson, 1952):

$$LAI = \frac{\text{Total LA}}{\text{Total land area}} \quad (7)$$

Recovery efficiency (RE) of added nitrogen (N) was calculated from the equation (Dilz, 1988):

$$RE = \frac{\text{(Total N uptake (kg ha}^{-1}\text{) treatment - Total N uptake (kg ha}^{-1}\text{) control)}}{\text{(Applied N (kg Nha}^{-1}\text{) treatment)}} \quad (8)$$

Agronomic efficiency (AE) of added N was obtained as (Novoa and Loomis, 1981):

$$AE \text{ (kg grain kg N applied}^{-1}\text{)} = \frac{\text{Grain yield (kg Nha}^{-1}\text{) treatment- grain yield (kg Nha}^{-1}\text{) control}}{\text{Applied N (kg Nha}^{-1}\text{) treatment}} \times 100 \quad (9)$$

2.6 Statistical Analysis

Analysis of variance (ANOVA) was performed on data collected. Differences among the treatments and their interactions were tested with an orthogonal contrast test to assess their significance (SAS Institute, 1989). Duncan's Multiple Range Test (DMRT) was used to compare treatment means at the 0.05 level of probability.

3.0 RESULTS AND DISCUSSION

The coarse-textured soils of the site were freely draining and cultivation was relatively easy. The soil profile indicated a low fertility status. The total nitrogen content of the soil varied from 0.04 to 0.09%,w/w while the effective CEC. varied from 5.2 to 7.7 meq/100g soils (Table 1). Soil pH in KCl decreased from 5.8 in 1997 to 5.5 in 1999. Since the soil structure was poor in the plough layer, the soil bulk density tended to rise rapidly after tillage operation thereby impeding root development and plant growth. Rainfall varied from 608mm to 1482mm per annum (Fig. 1). Annual temperature ranged from 30.9°C to 31.,3°C with slight daily variation (S.D: 1.822-2.860; C.V:5.821-9.375%) as shown in Table 2. Rainfall distribution was poor in 1997, particularly in May-July. The crops were stressed during seedling emergence and grain fill. Much of the rainfall in August, 1997 occurred late and did not improve the crop growth much. Three-year (1997-1999) means of maize grain yield are shown because the treatment x year interaction was not significant (Table 5). Similar results were obtained with most other variables considered. The higher maize grain yield in plots of disc ploughing followed by disc harrowing and disc ridging (T4) than other tillage practices may have been partly due to lower cone index (1.92MPa) and higher soil moisture content(24.70%, w/w) (Table 4). The practical implication is that tillage treatments had great effects on crop yield. This result agrees with those of Lal and Tanaka (1992) who concluded that tillage methods had a drastic effect on maize yield.

Increased soil resistance to penetrometer pressure decreased maize grain yield. This result is in agreement with that of Katcheson (1980) who attributed reduction in maize yield to soil compaction. There were high soil dry bulk density and mean period of ultimate emergence with subsequent low 100-kernel weight due to high soil strength. In shallow tilled plots of T1 and T2, soil water reached the subsoil layer mostly by percolation through macro pores of the tilled soil matric into the untilled (compacted) or smeared layer. An increase in soil moisture content from 15.72 to 24.70%, w/w, had a marked increase on maize grain yield from 2.77 to 5.60 t ha^{-1}. Increase in soil moisture content resulted in reduction of soil penetration resistance with effect on soil dry bulk density (Fig. 2a). Rickman et al. (1983) and Cote and Ramsey (1983) reported similar findings. Bulk density profile showed the presence of a zone of greater soil dry bulk density with increase in depth (15-30cm) of tillage (Fig. 2b). This suggests a probable development of a tillage pan below 15cm soil depth. This result is consistent with the lower bulk density in the top soil than in the subsoil, as reported by Carter and Steel (1992).

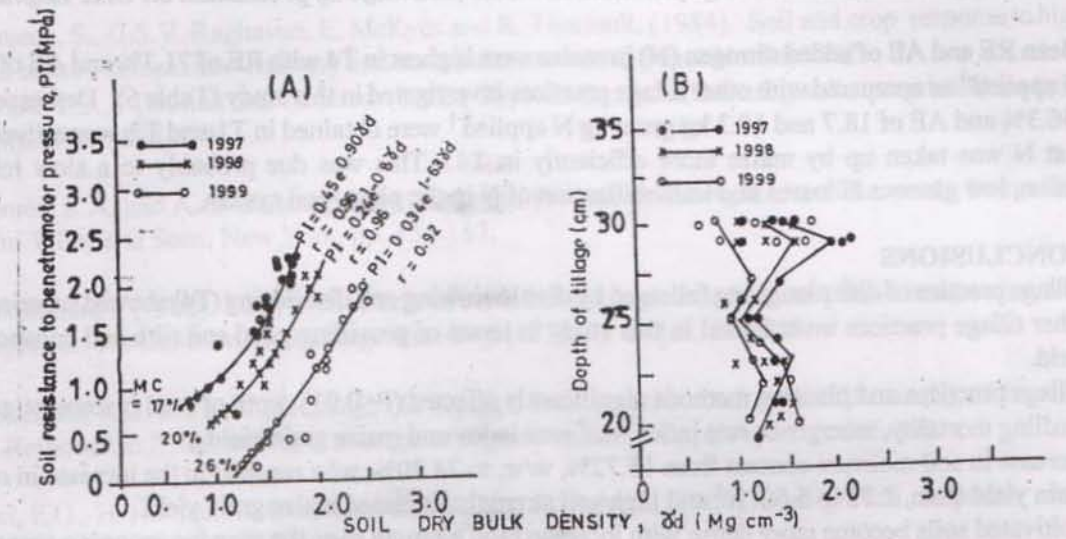

Fig. 2: Effect of soil dry bulk density on (A) soil resistance to penetrometer pressure and (B) depth of soil tillage.

Leaf area index (LAI) increased from 1.5 in T4 at 20 days after sowing (DAS) to the peak of 5.5 at 80 DAS, but later declined gradually (Fig. 3). Tillage practice significantly affected ($P \leq 0.01$) the seed and seedling mortality, emergence rate index, leaf area index and maize grain yield (Table 5). Good soil tilth of medium aggregate seedbeds, high tillage depth and crop yield were provided by T4. It proved advantageous in accelerating emergence of seedlings, and crop growth due probably to improved soil moisture supply. The depth of seed placement was significantly affected ($P \leq 0.01$) by the planting methods (Table 5). Manual method of planting could not produce uniform depth of seed placement while the single-row animal-drawn planter placed the seed into the soil at a fairly uniform depth.

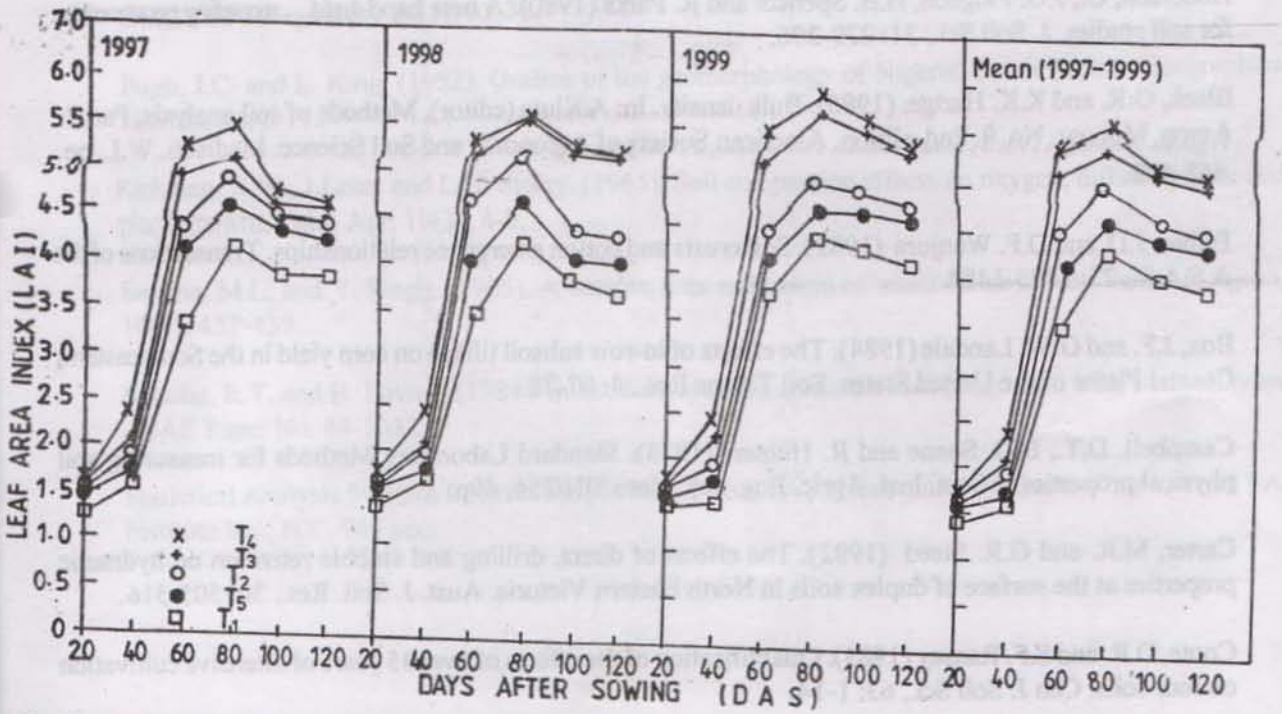

Fig. 3: Leaf area index as influenced by different tillage treatments on a sandy-loam soil at Sumaru, Nigeria.

Mean RE and AE of added nitrogen (N) in maize were highest in T4 with RE of 71.3% and AE of 22.7 kg grain kg N applied^{-1} as compared with other tillage practices investigated in this study (Table 6). Depressed RE of 51.0 and 56.3% and AE of 18.7 and 18.3 kg grain kg N applied^{-1} were obtained in T1 and T2, respectively. This implies that N was taken up by maize more efficiently in T4. This was due probably to a slow release of mineralization, low gaseous N losses and immobilization of N in the plant -soil system.

4.0 CONCLUSIONS

1. Tillage practice of disc ploughing followed by disc harrowing and disc ridging (T4) showed superiority over other tillage practices investigated in this study in terms of providing good soil tilth and enhanced crop yield.
2. Tillage practices and planting methods significantly affected ($P \leq 0.01$) depth of seed placement, seed and seedling mortality, emergence rate index, leaf area index and maize grain yield.
3. Increase in soil moisture content from 15.72%, w/w, to 24.70%, w/w resulted in the increase in of maize grain yield from, 2.77 to 5.60t h^{-1} and high soil strength decreased maize grain yield.
4. Cultivated soils become more dense with increased soil strength over the growing cropping seasons.
5. The highest RE of 71.3% and AE of 22.7 kg grain kg N applied^{-1} were obtained in T4 implying that N was taken up by maize more efficiently than other tillage practices studied. This was due probably to slow losses and immobilization of N in the plant-soil system.

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REFERENCES

Anderson, G., J.G. Pidgeon, H.B. Spencer and R. Parks.(1980). A new hand-held recording penetrometer for soil studies. J. Soil Sci., 31: 279-296.

Black, G.R. and K.K. Hartge. (1986). Bulk density. In: A Klute (editor), Methods of soil analysis, Part 1. Agron. Monogr. No. 9, 2nd edition. American Society of Agronomy and Soil Science. Madison, W.I., pp. 463-478.

Bilbro, J.D. and D.F. Wanjura (1982). Soil crusts and cotton emergence relationships. Transactions of the A.S.A.E., 25: 1485-1488.

Box, J.F. and G.W. Landale (1984). The effects of in-row subsoil tillage on corn yield in the Southeastern Coastal Plains of the United States. Soil Tillage Res., 4: 67-78.

Campbell, D.T., B.D. Soane and R. Hunter (1978). Standard Laboratory Methods for measuring soil physical properties at Scot. Inst. Agric. Eng. Pep. Note SIN/256, 49p.

Carter, M.R. and G.R. Steed (1992). The effects of direct, drilling and stubble retention on hydraulic properties at the surface of duplex soils in North Eastern Victoria. Aust. J. Soil. Res., 30: 505-516.

Coote, D.R. and S.F. Ransey (1983). Quantification of the effects of over 35 years of intensive cultivation on four soils. Can J. Soil Sci., 63: 1-14.

Dilz; K (1988). Efficiency of uptake and utilization of fertilizer nitrogen by plants. In D.D. Jenkinson and K.A. Smith (ed.). Nitrogen efficiency in agricultural soils. Elsevier Applied Science, London. p. 1-26.

DuBois, D. and E.F. Dubois (1916). Arch. Intern. Med., 15: 868.

Gameda, S., G.S.V. Raghavan, E. McKyes and R. Therioult. (1984). Soil and crop response to high axle load subsoil compaction-recovery and accumulation. ASAE Paper No. 84-1542.

Gerard, C.J., P. Saxton and G. Shaw (1982). Physical factors influencing soil strength and root growth. Agron. J. 74: 875-879.

Gomez, K.A. and A.A. Gomez (1984). Statistical Procedures for Agricultural Research. Second edition. John Wiley and Sons, New York. pp. 154-167.

Hakansson, I. (1982). Long term effects of vehicles with high axle load on subsoil compaction and crop responses. 9th Conf. Int. Soil Tillage Res. Org. (ISTRO), Osijek, 213-218.

Heathcote, R.G. and K.R. Stockinger (1970). Soil fertility under continuous cultivation in northern Nigeria. II. Response to fertilizers in the absence of organic manures. Expl. Agric., 6: 345-350.

Idel, E.G., H. Hafman, L. Ossemerct and M. Van Ruymbeke. (1984). Root-growth response of winter barley to subsoiling. Soil Tillage Res., 4: 419-431.

Johnson, R.E., L. Brouba and R.C. Darling. (1942). A test of physical fitness for strenuous exertion. Review of Canadian Biology, 1: 491.

Joshi, N.L., (1987). Seedling emergence and yield of pearl millet on naturally crushed arid soils in relation to sowing and cultural methods. Soil Tillage Res., 10(2): 103-112.

Katcheson, J.W., 1980. Effect of tillage on fertilizer requirements for corn on a silt loam soil. Agron. J., 72: 540-542.

Lal, R. and H. Tanaka. (1992). Simulated harvest traffic effects on corn, oats and soybean yield in Western Ohio. Soil Tillage Res., 24(1): 65-78.

Pugh, J.C. and L. King. (1952). Outline of the geomorphology of Nigeria. South African Geographical Journal, 34: 5-14.

Rickman, R.W., J.Letey and L.H. Stolzy. (1965). Soil compaction effects on oxygen, diffusion rates and plant growth. Calif. Agr. 19(3): 4-6.

Saxena, M.L. and Y. Singh. (1965). A note on area estimation of intact maize leaves. Indian J. Agron., 10(4): 437-439.

Schular, R.T. and B. Lavery. (1984). Subsoil compaction effect on corn production with two soil types. ASAE Paper No. 84-1032.

Statistical Analysis Systems Institute Inc., (1989). SAS/STAT User's guide, Version 6. 4th Edn., Vol. 1 SAS Institute Inc., N.C. 943 pp.

Valette, J. and LJ. Ibanga. (1984). The detailed soil survey of the experimental farm of the Institute for Agricultural Research, Samaru, Zaria, Nigerian. Soil Survey Bulletin, 95pp.
Watson, D.J. (1952). The physiological basis of variation in yield. Adv. Agron., 41: 101-145.

Yusuf, D.D. (1996). Time and cost conserving farming technique for the resource poor farmers in tropical Africa. Journal of Engineering for International Development, 2(3):31-37.

Yusuf, D.D. (2001). Deep ploughing effects on irrigation intake, bulk density and soil compaction on of slowly permeable soil in northern Nigeria. Nigerian Journal of Engineering, 9(1):22-26.

Table 4: Effect of tillage treatments on maize grain yield at Samaru, Nigeria

Tillage treatment	Crop Assesment Parameters[1]								
	Cone index (MPa)	Soil moisture contents (%, w/w)	Soil dry bulk density ($mgcm^{-3}$)	Mean period of ultimate emergence (days)	Days from planting to mid-anthesis (days)	Days from planting to mid-silking (days)	Plant heights[2] (cm)	100-kernel weights[3] (g)	Maize grain yield ($t\ ha^{-1}$)
T1	4.32 ±0.40	15.72 ±0.20	1.57 ±0.50	6.40 ±0.39	60.50 ±1.50	77.50 ±4.39	163.00 ±4.32	53.95 ±1.80	2.77 ±0.17
T2	4.01 ±0.72	17.00 ±0.11	1.53 ±0.71	6.30 ±0.19	62.30 ±2.48	72.00 ±2.12	171.00 ±2.24	56.80 ±1.58	3.74 ±0.14
T3	2.84 ±0.41	22.30 ±0.31	1.39 ±0.92	6.00 ±0.18	63.80 ±2.59	78.50 ±3.20	174.50 ±2.96	64.23 ±1.92	4.78 ±0.09
T4	1.92 ±0.77	24.70 ±0.29	1.52 ±0.65	6.00 ±0.22	60.00 ±4.42	70.20 ±1.78	167.25 ±2.86	68.88 ±1.92	5.60 ±0.21
T5	3.11 ±0.84	20.00 ±0.19	1.53 ±0.65	6.40 ±0.25	62.50 ±1.60	78.50 ±2.29	167.25 ±2.86	55.45 ±2.29	3.42 ±0.14
$\bar{x}$	3.24	19.94	1.49	6.22	61.80	75.60	170.53	59.86	4.06
SD	0.86	3.31	0.07	0.37	3.06	4.16	5.74	5.73	1.01
CV (%)	26.54	16.61	4.70	5.10	4.90	5.50	3.40	9.57	24.88

1) Each value is a mean of 3-year (1997-1999) data ±standard deviation
2) Measurements made 60 days after planting
3) Grain moisture content - 20%
Note $\bar{x}$ = mean; SD = standard deviation; CV = coefficient of variation

Table 5: Combined analysis of variance for seedling emergence, maize growth and grain yield data

Source of Variation	df	Variable				
		Depth of seed placement	Seed and seedling mortality	Emergence rate index	Leaf area index	Maize grain yield
		<----------Mean squares and significance of F ---------->				
Replication	3	60.083	62.444	69.621	265.871	10.942
Years (Y)	2	341.425**	280.633**	1.168ns	0.558ns	14.637**
Reps (Y)	6	12.692	9.078	4.636	0.789	1.376
Vertical factor (A)	3	4.661**	0.450ns	0.810ns	2.421ns	0.256ns
Y x A	6	1.436ns	0.642ns	0.081ns	0.1054ns	0.031ns
Rep (Y x A)	27	5.757	4.710	0.140	0.121	0.017
Horizontal factor (B)	4	5558.507**	5693.283**	37.583**	25.483**	37.038**
A x B	12	3.267**	1.158ns	0.082ns	0.038ns	0.009ns
Y x B	8	35.107**	33.758**	1.829ns	0.158ns	1.201ns
Y x A x B	24	7.344**	1.756**	0.067ns	0.033ns	0.193ns
Reps (Y x A x B)	144	9.178	6.491	0.595	0.209	0.249
Subplot factor (C)	1	2679.075**	2539.200**	40.542**	13.872**	9.344**
A x C	3	0.125ns	4.606**	0.146ns	0.040ns	0.024ns
B x C	4	220.289**	243.617**	1.056ns	0.080ns	0.129ns
Y x C	2	1.975ns	1.900ns	13.238**	0.137ns	1.274ns
A x B x C	12	2.012*	6.175**	0.100ns	0.031ns	0.021ns
Y x B x C	8	14.095**	14.692**	0.351ns	0.032ns	0.598ns
Y x A x B x C	30	4.701**	3.228**	0.111ns	0.023ns	0.020ns
Error	180	8.653	5.335	0.215	0.044	0.137
Total	479					

*, ** = Significant at 0.05 and 0.01 probability levels, respectively; ns = not significant.

Table 6: Recovery and agronomic efficiencies of nitrogen fertilizer on maize as influenced by tillage

Tillage practice	Recovery efficiency (%)#				Agronomic efficincy (kg grain kg N applied^{-1})#			
	1997	1998	1999	Mean	1997	1998	1999	Mean
T1	50d	52d	51d	51.0d	22ab	19b	15c	18.7bc
T2	51d	60bc	58c	56.3c	22ab	18bc	15c	18.3bc
T3	62b	67ab	61b	63.3b	23a	22ab	20b	21.7ab
T4	70a	71a	73a	71.3a	24a	23a	21ab	22.7ab
T5	57c	61b	56c	58c	22ab	18bc	20b	20.0b
$\bar{x}$	58.0	62.2	59.8	59.98	22.6	20.0	18.2	20.3
SD	7.403	6.493	7.359	6.889	0.800	2.098	2.638	1.695
CV(%)	12.763	10.439	12.306	11.486	3.540	10.490	14.495	8.300

#Values within the column followed by same letter do not differ significantly ($P \leq 0.05$) by Duncan's Multiple Range Test (DMRT).
Note: $\bar{x}$ = mean; SD = standard deviation; CV = coefficient of variation

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INFLUENCE OF COOKING TIME ON THE CRACKABILITY OF CONOPHOR NUTS

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ABSTRACT

Fresh conophor nuts (*Tetracapidium conophorum*) must be cooked and the thick shell removed before the edible kernel can be processed into food or for industrial use. The relationship between cooking time and the crackability of the nuts is therefore important. Fresh conophor nuts were sun-dried for 4 days to bring the moisture content to about 66.0 ± 1.3% (db). They were put into continuously boiling water and allowed to cook for T = 60, 75, 90, 105 and 120 minutes respectively. Each set of 100 nuts was allowed to cool for 24 hours in a de iccator before cracking tests were done using the cracking energy instrument. Cracking energy decreased with increase in cooking time averaging from 0.14J for T = 60 mins. to 0.08J for T = 120 mins. Full cracking of over 80% was obtained for longer cooking times of between 105 and 120 mins. for average impinging velocity of between 3.47 and 3.80 m/sec. While cracking energy increased linearly with impinging velocity, nut radial diameter also increased linearly with nut mass for all cooking times.

KEYWORDS:
Conophor nuts, Crackability, Cooking time, Cracking energy, Impinging velocity, *Tetracarpidium conophorum*.

1.0 INTRODUCTION

Heat treatment, such as cooking and precooking, of agricultural materials is an important preparation process for numerous applications: hard seeds of legumes are treated with high temperatures to make them permeable to water and improve germinating quality; hard-to-cook phenomena of African yam bean has been reduced drastically by precooking (Njoku, et al., 1989; Irtwange and Igbeka, 2002); the hard nature of the dry mature seeds of nutritious Pigeon pea (*Cajanus cajan*) need to be cooked until tender before further processing (Enwere, 1998; Oluka and Bardey, 2001); parboiling of rice paddy to heal kernel defects (cracks) and improve milling quality (Farouk and Islam, 1995); cooking of oil seeds/fruits to break down the mesocarp and rupture the oil cell to improve oil yield (Ward, 1976; Hartley, 1988); cooking breaks down the triglyceride in vegetable oil for industrial processing Faborode, (1996). Makanjuola (1978), Fasina and Ajibola (1989) and Asoegwu (1995) have described the nutritional and industrial importance of conophor nuts.

Cooking is essential before the edible kernel of conophor nuts (African walnut) can be extracted. This is because the nuts have hard black shells, which must be removed before the kernel or cotyledon can be processed into food or for industrial use. Makanjuola (1978) developed an extraction machine for conophor nuts. The machine was not tested with cooked conophor nuts. However, studies have indicated that cooking affects textural changes in cell wall materials and firmness (Kon, 1968; Manabe, 1980; Wu and Chang, 1990). One is justified in expecting that cooking can affect the hard black shells of conophor nuts (Fig. 1), which will have direct relationship with the nuts crackability.

The development of a mechanical cracking machine would require the knowledge of the cracking energy of the conophor nuts for determining the appropriate rotating impeller velocity that will impinge the nuts on a hard surface for cracking the nut and releasing the kernel. The nuts must possess the required kinetic energy at impact and the rotor must be made to transmit this energy.

It is the objective of this study to investigate the effect of cooking time on conophor nuts, on the crackability of the nuts to release the edible kernel. The crackability obtained was used to determine the range of the appropriate rotating impeller velocities for cracking cooked conophor shell and releasing the kernel.

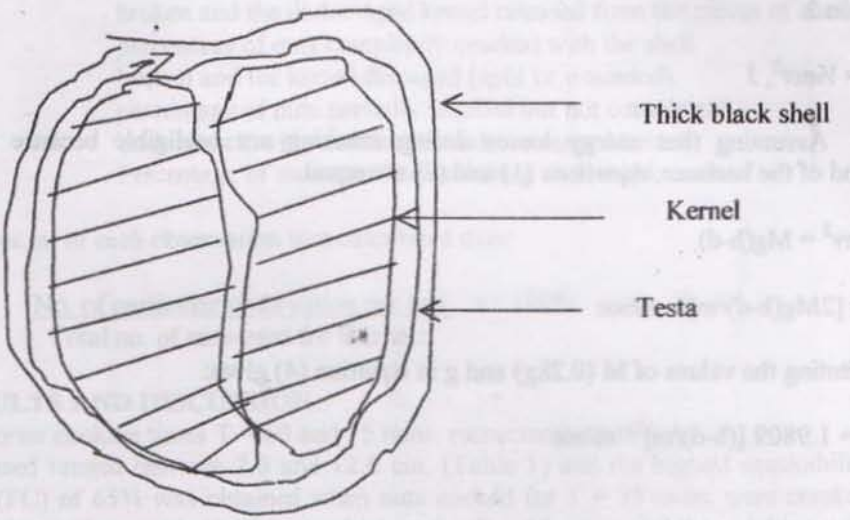

Fig. 1 Cross-section of the conophor nut

2.0 MATERIALS AND METHODS

Freshly harvested fruits of African walnut (*Tetracarpidium conophorum*) were processed traditionally to obtain the nuts which, were sun-dried for 4 days to bring the moisture content to about 66.0 ± 1.3% (db). The moisture content was obtained using the ASAE Standards (1998). Five hundred conophor nuts of radial diameter ranging from 2.72 to 3.15 cm, measured using a vernier caliper were immersed in boiling water. The nuts were left in continuously boiling water to cook for up to 2 hours. At 60, 75, 90, 105 and 120 minutes, 100 nuts were removed and cooled in a dessicator for 24 hours. Each nut was weighed using an electronic top loading weighing balance and recorded to the second decimal in g, and the radial diameter measured before the cracking energy was determined using the nut-cracking instrument (Fig. 2). Of the many impact-inducing devices the simple drop test apparatus has been widely used. The instrument is similar to the one used by Fluck and Ahmed (1973), Wright and Splinter (1968), and Dienagha and Ibanichuka (1991). The instrument has been described in Asoegwu (1995) and Asoegwu and Maduike (1999).

The cracking instrument consists of a 0.2kg weight (hammer) constrained to move vertically in an open-ended metal cylindrical container, which rests on a flat metal plate. The hammer is raised through a small pulley. The thickness of the flat base plate is 6mm. A graduated scale (ruler) was used to measure the drop height of the hammer to crack the conophor nut placed on its radial diameter at the middle of the base plate. Preliminary tests showed that impacts to the side, radial diameter resulted in more splits than impacts to the top Asoegwu (1995). Hoki and Pickett (1973) and Bartsch et al. (1986) have reported the same observation for navy bean and soybean respectively.

2.1 Cracking Theory

The cracking of the nut is achieved either by a blow of a hammer on a static nut on a hard surface or by throwing the nut with appropriate kinetic energy onto a hard static surface. The potential energy (P.E.) of the hammer of mass, M, falling vertically from height, h, to crack a nut of mass, m, with radial diameter, d, (Fig. 2) is given by equation 1.

$$P.E. = Mg(h-d), J \quad (1)$$

Where g = gravitational acceleration, 9.81 m/s^2

If being flung onto a hard static surface cracks the nut, the wall absorbs the kinetic energy (K.E.) of the nut due to its impinging velocity, v, and normal to the surface. The K.E. equation is given by equation 2.

$$K.E. = \tfrac{1}{2}mv^2, J \quad (2)$$

Assuming that energy losses during cracking are negligible because there is no appreciable rebound of the hammer, equations (1) and (2) are equal.

$$\therefore \tfrac{1}{2}mv^2 = Mg(h-d) \quad (3)$$

$$\therefore v = [2Mg(h-d)/m]^{1/2} \text{ m/sec} \quad (4)$$

Substituting the values of M (0.2kg) and g in equation (4) gives:

$$V = 1.9809\,[(h-d)/m]^{1/2} \text{ m/sec} \quad (5)$$

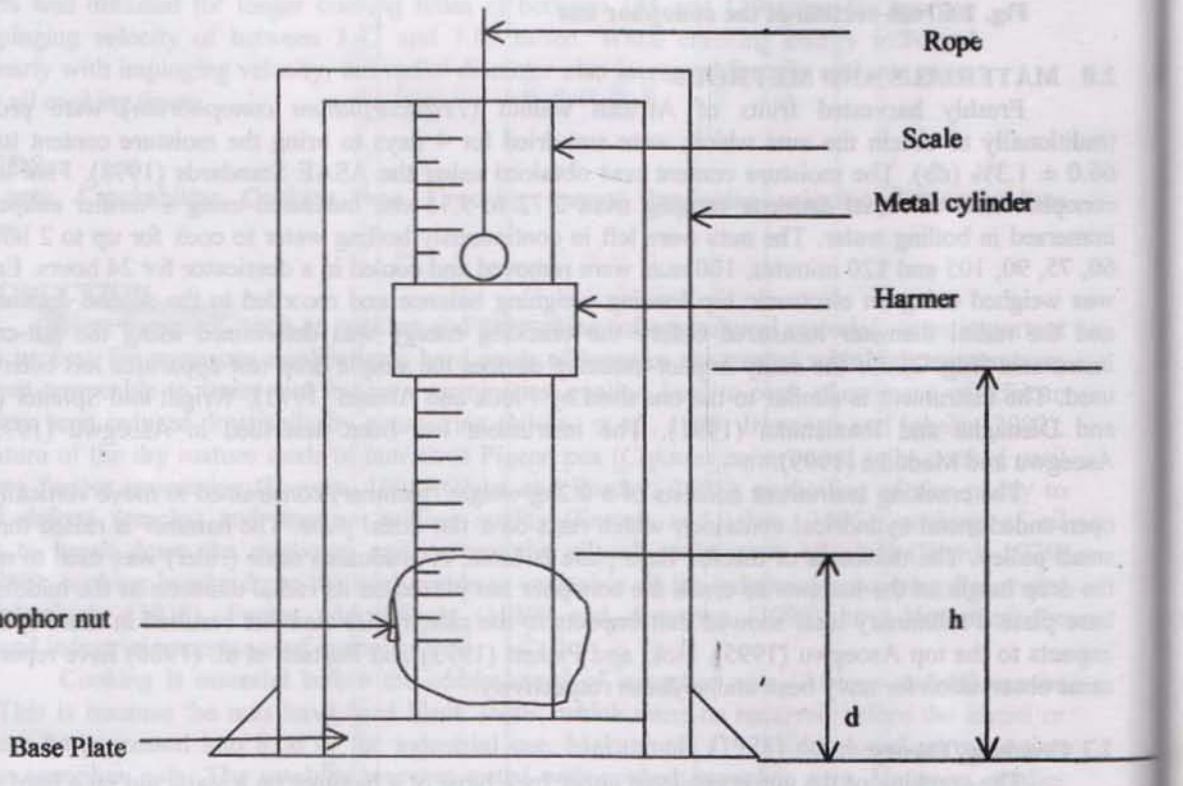

Fig. 2 Nut cracking energy instruments showing component parts and placement of nut and measured dimensions

2.2 Assessment of cracking

Cracking was assessed by visual observations of the following:

FC	-	percentage of nuts completely cracked with the shell broken and the undamaged kernel released from the pieces of shell.
FCW	-	percentage of nuts completely cracked with the shell broken and the kernel damaged (split or wounded).
VC	-	percentage of nuts partially cracked but not completely broken shell with undamaged and unreleased kernel.
SM	-	Percentage of nuts smashed including shell and kernel

The percentages, n, of each observation was calculated thus:

$$N = \frac{\text{No. of particular observation per test}}{\text{Total no. of nuts used for that test}} \times 100\% \quad (6)$$

3.0 RESULTS AND DISCUSSION

At shorter cooking times T = 60 and 75 mins. respectively, test drop Heights (H) used ranged between 7.0 and 12.0 cm. (Table 1) and the highest crackability i.e. maximum full cracking (FC) of 65% was obtained when nuts cooked for T = 75 mins. were cracked using H = 9.0 cm. Full cracking with wounds (FCW) was highest for T = 60 mins. and the cracking was achieved using H = 12 cm. High drop heights mean high P.E. which indicate that cooking for shorter times had not softened the shells as they were still hard. The percentage visible cracks (VC) recorded generally decreased with increase in drop height and cooking times.

For T = 75 and 90 mins., the crackability increased with increase in drop height, reaching 90% at H = 9 – 10 cm for T = 90 mins. For T = 105 and 120 mins., the crackability was greater than 80% for all drop heights reaching 100% at H = 8.0 cm for T = 105 mins. and H = 6.0 and 8.0 cm for T = 120 mins. The above results show that crackability increased with increased cooking times. On the average, for over 80% crackability, it may be suggested that conophor nuts be cooked for over 90 mins. before shelling using drop heights > 7.0 cm. When cooked for T = 105 and 120 mins., conophor nuts had no wounded kernels (FCW) when cracked using H = 6.0 – 8.0 cm (Fig. 3).

For T = 60 and 75 mins., the % FCW and smashed nuts (SM) increased with increase in H > 9.0 cm. At these cooking times, there may not have been enough cracks on the shell, caused by cooking, for easy release of the kernels thus causing the kernels to be either damaged or smashed, with only about 40 – 65% crackability. For T = 90 mins., FCW and SM did not exceed 10% for all drop heights showing that prolonged cooking gave enough multiple cracks to the shells for higher crackability. From Fig. 3, it is also observed that FC increased to high values at some drop heights and decreased as the drop height increased further. This shows that there is range of drop heights at which crackability can be optimum. This has been observed for palm nuts (Dienagha and Ibanichuka, 1991).

When averaged over all test drop heights, the maximum FC of 92% was recorded at T = 120 mins. (Fig.4). Percentage FC increased with increase in T because cooking tends to heat up the shell and expand it while cooling contracts it. The process of expansion and contraction of the shell precipitates cracking. The longer the nuts are cooked the more cracks are initiated in the shells (stress-cracking). This improves crackability. Full cracking of conophor nuts can be predicted using equation 7.

$$FC = 4.0 + 0.7733T \quad (r = 0.9609) \quad (7)$$

Also from Fig. 4, all the other evaluation parameters (VC, FCW, and SM) tended to decrease with increase in T for all H tested. FCW did not exceed 10% which was recorded at T = 75 mins., while the highest 4% of SM was recorded at T = 90 mins. It is evident from these results that T<105mins. should not be used as a preparation parameter for conophor nuts.

Table 1. Percentage of each cracking assessment as influenced by cooking time and drop test height

Cooking time (mins)	Drop height (cm)	Percentage of each observation[a]			
		VC	FC	FCW	SM
60	8.0	60	40	0	0
	9.0	55	45	0	0
	10.0	35	60	5	0
	11.0	20	60	15	5
	12.0	15	50	25	10
75	7.0	50	45	5	0
	8.0	45	50	5	0
	9.0	25	65	10	0
	10.0	25	60	10	5
	11.0	10	60	20	10
90	6.0	40	60	0	0
	7.0	20	75	5	0
	8.0	15	80	0	5
	9.0	0	90	0	10
	10.0	0	90	5	5
105	5.0	10	80	10	0
	6.0	15	85	0	0
	7.0	5	90	0	5
	8.0	0	100	0	0
	9.0	0	95	0	5
120	5.0	15	80	5	0
	6.0	0	100	0	0
	7.0	0	95	0	5
	8.0	0	100	0	0
	9.0	0	85	10	5

a. Each row is an average of 20 nuts of different mass and radial diameter.

Fig. 5 shows the percentage crackability for cooking times averaged for each drop height. FC decreased linearly with increase in drop height as given by equation 8.

$$FC = 104.94 + 3.993H \quad (r = -0.9033) \qquad (8)$$

The highest FC (81.7%) was recorded at H = 6.0 cm while the lowest of 50% was recorded at H = 12 cm. Over FC = 70% was recorded for H < 10.0 cm, while VC was between 12 5 and 24% for all H tested. For H > 9.0 cm the FCW and SM increased sharply to 25% and 10% respectively at H = 12.0 cm. This is due to the high incidence of smashed or wounded kernels at low cooking times and high drop heights. Again it can be said that high drop heights mean high P.E., which when exceeded, the cracking energy of the nuts wounds or smashes them.

Table 2 shows that for T> 90 mins. the highest % of nuts were fully cracked meaning that conophor nuts should be cooked for 90 mins. to take advantage of any cracking machine like the one developed by Makanjuola (1978). It is observed that for various nut mass (m) and radial diameter (d), the cracking energy (CE) for conophor nuts decreased with increasing cooking time (T) and so is the impinging velocity (v) required to crack the nuts. For this study, m varied from 9.85 to 15.85 g and d from 2.64 to 3.28 cm for the various cooking times. For the various cooking times, it was observed that radial diameter is linearly related to the nut mass as shown in Table 3. For all the nuts used in the test and for all the cooking times equation 9 shows the relationship between the radial diameter and the nut mass.

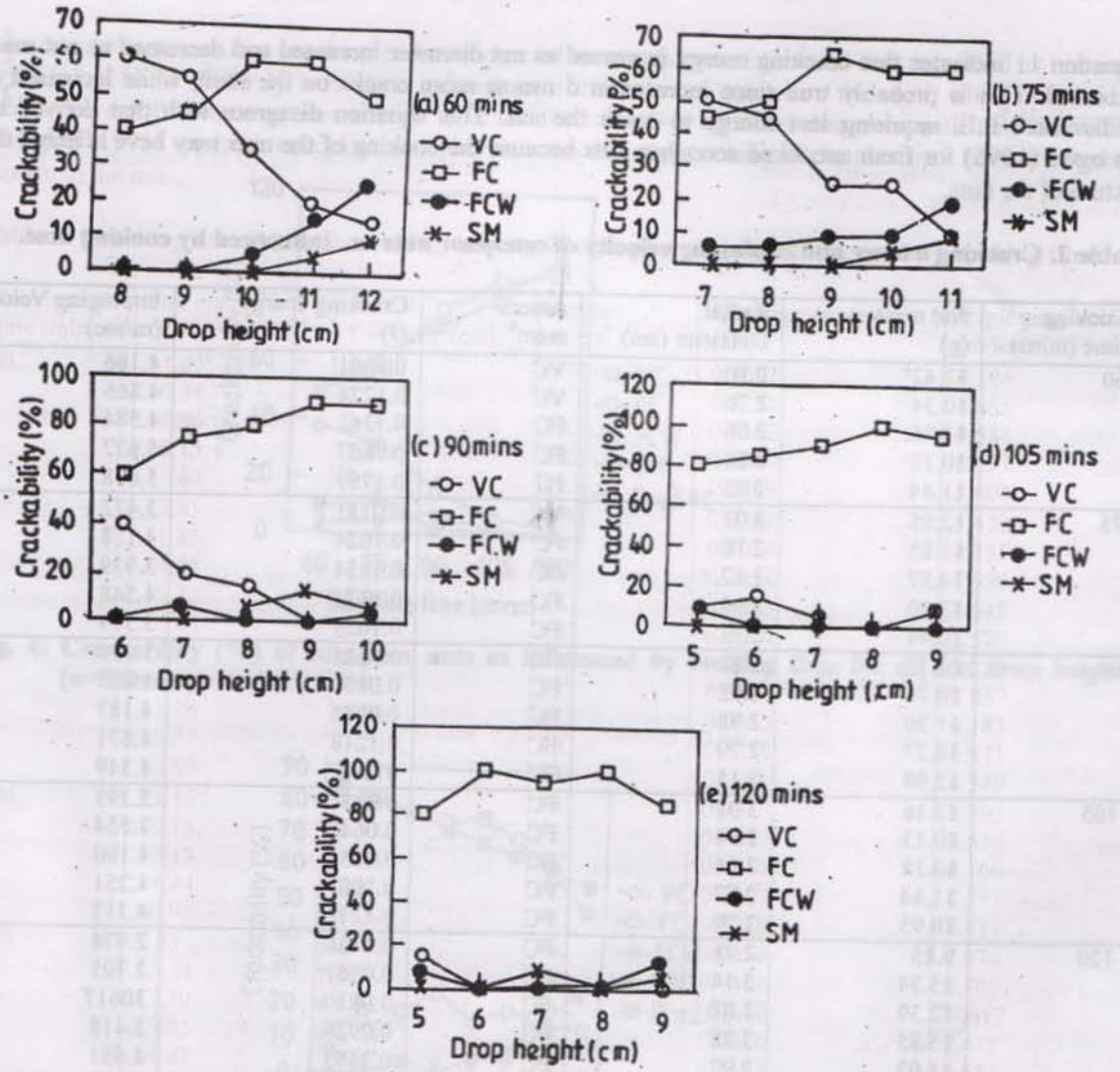

Fig. 3: Percentage crackability of conophor nuts as influenced by drop height for different cookoing times (a) to (e)

$$d_w = 1.903 + 0.0849m \quad (r = 0.8938) \tag{9}$$

Since the drop test apparatus was used, the CE will depend on m and d of the conophor nut and the generalized multiple regression equation is given by:

$$CE = a_o + a_1 m + a_2 d \tag{10}$$

Where a_o, a_1, and a_2 are constants.

Allowing for the conditions that give over 85% crackability i.e. T = 90 mins. and H = 9 and 10 cm; T = 105 and 120 mins. and H = 6 – 9 cm, a multiple regression equation relating nut mass and radial diameter to cracking energy was developed to give:

$$CE = -4.72 \times 10^{-4} - 12.65m + 8.59d \quad (R^2 = 0.874) \tag{11}$$

Equation 11 indicates that cracking energy increased as nut diameter increased and decreased as nut mass increased. This is probably true since increase in d means more cracks on the shell, while increased m means more P.E. requiring less energy to crack the nut. This equation disagrees with that derived by Asoegwu (1995) for fresh uncooked conophor nuts because the cooking of the nuts may have affected the texture of the nuts.

Table 2. Cracking energy and impinging velocity of conophor nuts as influenced by cooking time.

Cooking time (mins)	Nut mass (g)	Radial Diameter (cm)	Assess-ment[b]	Cracking energy (J)	Impinging Velocity (m/sec)
60	11.42[b]	2.90	VC	0.1001	4.186
	10.34	2.76	VC	0.1224	4.866
	12.96	3.06	FC	0.1362	4.584
	10.15	2.81	FC	0.1607	5.627
	11.44	2.83	FC	0.1799	5.608
75	12.95	3.02	VC	0.0781	3.472
	11.85	2.78	FC	0.1024	4.158
	14.87	3.12	FC	0.1154	3.939
	13.30	2.99	FC	0.1375	4.548
	10.44	2.72	FC	0.1624	5.579
90	11.12	2.81	FC	0.0626	3.355
	10.76	2.92	FC	0.0800	3.857
	11.26	2.98	FC	0.0985	4.183
	10.27	2.79	FC	0.1218	4.871
	12.99	3.15	FC	01344	4.549
105	13.16	3.08	FC	0.0377	2.393
	10.13	2.74	FC	0.0640	3.554
	10.18	2.64	FC	0.0855	4.100
	11.44	2.87	FC	0.1007	4.251
	10.95	*2.79*	*FC*	*0.1218*	*4.717*
120	9.85	2.78	FC	0.0436	2.974
	15.34	3.14	FC	0.0561	2.705
	12.39	2.87	FC	0.0810	30617
	15.85	3.28	FC	0.0926	3.418
	11.03	2.92	FC	0.1193	4.651

a. Each row is an average of 20 nuts at different test heights not > 12 cm.
b. Assessment shows where the highest % crackability was found.

Table 3. Linear regression equations for radial diameter (cm) and nut mass (g) for different cooking times and all test drop heights.

Cooking time (mins)	Regression Equations	Correlations coefficients
60	$d = 1.778 + 0.0972m$	$r = 0.9350$
75	$d = 1.685 + 0.0979m$	$r = 0.9582$
90	$d = 1.491 + 0.1276m$	$r = 0.9011$
105	$d = 1.371 + 0.1300m$	$r = 0.9730$
120	$d = 2.042 + 0.0744m$	$r = 0.9474$
	$d_{ave} = 1.903 + 0.0849m$	$r = 0.8938$

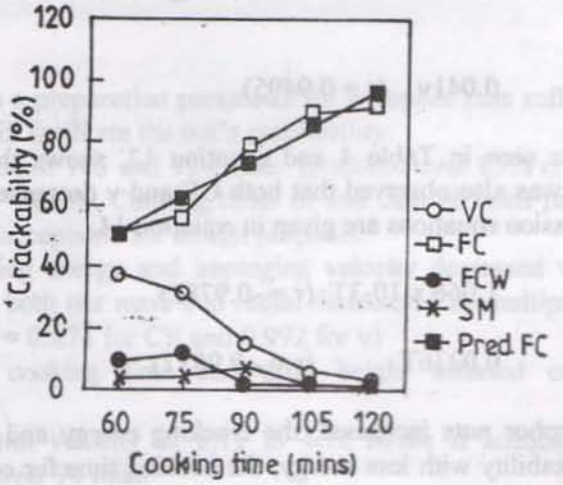

Fig. 4: Crackability (%) of conophor nuts as influenced by cooking time for all test drop heights (n=500nuts)

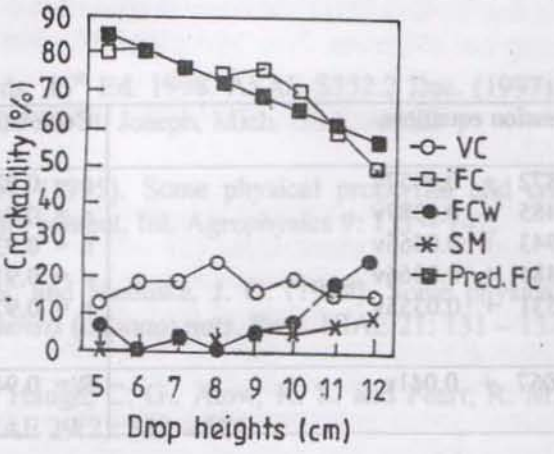

Fig. 5: Crackability (%) of conophor nuts at various test drop heights for all cooking times (n=500nuts)

Cracking energies of between 0.06J and 0.12J were sufficient to give over 90% crackability when the nuts were cooked for T > 90 mins. The lower values are for higher cooking times. The impinging velocities that gave the above CE ranged from 2.71 to 4.72 m/sec. This means that the impeller velocities in rpm should be such that the above impinging velocities, normal to the hard surface, are met when designing the cracking machine. The multiple regression analysis of nut mass and radial diameter against impinging velocity showed very high correlation.

$$v = -2.93 \times 10^{-3} - 565.92m + 372.37d \quad (R^2 = 0.992) \qquad (12)$$

Equation 12 validates equation 11 above since they followed the same trend. However, since various combinations of nut mass and radial diameter cooked for T > 90 mins. can give various CE and v, a range of values of these parameters would be required for design purposes. Knowing the average m and d, one can use equations 11 and 12 to determine the CE required per nut and the appropriate v to crack the nuts (T > 90 mins.) in a cracking machine. As should be expected the CE is linearly correlated to v for all the

cooking times tested. This is shown in Table 4. For all the cooking times tested the relationship between CE and v is given in equation 13.

$$CE = -0.067 + 0.041v \quad (r = 0.9495) \qquad (13)$$

The high correlation coefficient, as seen in Table 4 and equation 13, shows that CE is very linearly correlated to impinging velocity. It was also observed that both CE and v decreased linearly with cooking time as shown in Fig. 6. Their regression equations are given in equation 14.

$$CE = 0.1997 - 1.066 \times 10\text{-}3T \quad (r = -0.9782)$$

$$v = 6.2736 - 0.0236T \quad (r = -0.9837) \qquad (14)$$

Thus, as the cooking time of conophor nuts increased, the cracking energy and the impinging velocity both will decrease. For higher crackability with less energy, the cooking time for conophor nuts should be more than 90 mins.

Table 4. Regression equations of cracking energy and impinging velocity for different cooking times at all drop heights

Cooking time (mins)	Regression equations	Correlation coefficients
60	CE = - 0.0872 + 0.0457v	r = 0.9241
75	CE = - 0.0485 + 0.0387v	r = 0.9490
90	CE = - 0.0943 + 0.0465v	r = 0.9354
105	CE = - 0.0484 + 0.0366v	r = 0.9153
120	CE = - 0.0531 + 0.0355v	r = 0.9726
	CE_{ave} = - 0.067 + 0.041v	R = 0.9495

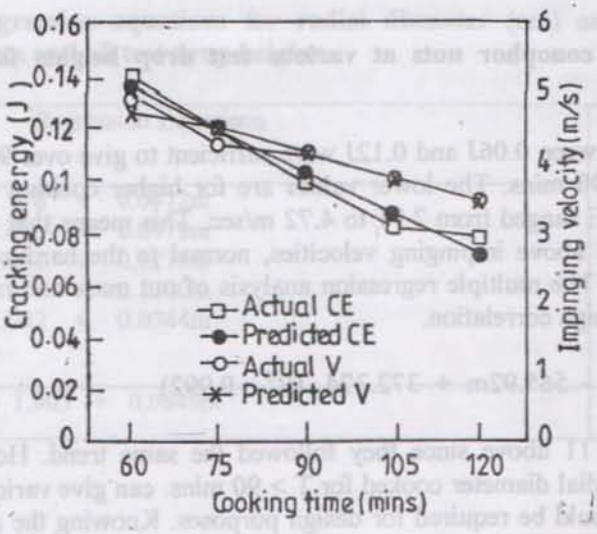

Fig. 6: Effect of cooking time on cracking energy (CE) and impinging velocity (V)

4.0 CONCLUSIONS

a. Cooking as a preparation parameter for conephor nuts softened the shell by forming cracks on the shell that will facilitate the nut's crackability.
b. Cooking time of 105 and 120 mins. produced over 85% crackability when the drop height ranged from 6.0 to 9.0 cm. Cooking times of less than 90 mins produced less than 65% crackability and may not be acceptable for design purposes.
c. Both cracking energy and impinging velocity decreased with increase in cooking time and are affected by both nut mass and radial diameter. The multiple regression coefficients were found to be high ($R^2 = 0.874$ for CE and 0.992 for v)
d. Generally, cooking time and drop height affected crackability positively and negatively respectively.
e. Impinging nut velocity of 2.71 to 4.72 m/sec is adequate for full cracking of conophor nuts cooked for over 90 mins

However, more work on these relationships in terms of increasing cooking time beyond 120 mins. is suggested. Also the above results should be tried on existing conophor nut cracking machines or used in future machine development.

REFERENCES

ASAE Standards, 45th Ed. 1998. ASAE S352.2 Dec. (1997). Moisture measurement: Unground grain and seeds, 551. St. Joseph, Mich. USA. ASAE

Asoegwu, S. N. (1995). Some physical properties and cracking energy of conophor nuts at different moisture content. Int. Agrophysics 9: 131 – 142.

Asoegwu, S. N. and Maduike, J. O. (1999). Some physical properties and cracking energy of *Irvingea gabonensis* (ogbono) nuts. Proc. NIAE 21: 131 – 137.

Bartsch, J. A., Haugh, C. G., Atow, K. L. and Peart, R. M. (1986). Impact damage to soybean seed. Trans ASAE 29(2): 582 – 586.

Dienagha, A. R. S. and Ibanichuka, O. K. (1991). Energy requirement for palm nut cracking. The Nigerian Eng., 26(3): 39 – 47.

Enwere, N. J. (1998). Foods of Plant Origin. Afro-Orbis Publications Ltd. Nsukka. Pp 57 – 59.

Faborode, M. O. (1996). Potentials for oilseeds in the rescue of a depressed economy. Proc. NSAE 18: 251 – 257.

Farouk, S. M. and Islam, M. N. (1995). Effect of parboiling and milling parameters on breakage of rice grains. AMA 26(4): 33 – 38, 43.

Fasina, O. O. and Ajibola, O. O. (1989). Mechanical expression of oil from conephor nut (*Tetracarpidium conophorum*). JAER 44: 275 – 287.

Fluck, R. C. and Ahmed, E. M. (1973). Impact testing of fruits and vegetables. Trans ASAE 16(4): 660 –666.

Hartley, C. W. S. (1988). The Oil Palm (*Elaeis guineensis*, Jacq.). Longmans Scientific and Technical Publishers, London.

Hoki, M. and Pickett, L.K. (1973). Factors affecting mechanical damage of navy bean. Trans ASAE 16(6): 1154 – 1157.

Irtwange, S. v. and Igbeka, J. C. (2002). Flow properties of African yam bean *(Sphenostylis stenocarpa)* as affected by accession and moisture content. Trans ASAR 45(4): 1063 – 1070.

Kon, S. 1968. Pectic substances of dry beans and their possible correlation with cooking time. J. of Food Sci. 33: 437 – 438.

Makanjuola, G. A. (1978). A machine for cracking conophor nuts. Appropriate Technology 5(1): 21 – 22.

Manabe, T. (1980). Studies on the firming mechanism of Japanese radish root by pre-heating treatment. Nippon Shokuhin Kogyo Gakkaishi. 27: 234 – 239.

Njoku, H. O., Eli, I. and Ofuya, C. O. (1989). Effect of pre-treatment on the cooking time of African yam bean *(Sphenostylis stenocarpa)*. J. Food Sci. 54: 758 – 759.

Oluka, S. I. and Bardey, I. A. (2001). The thermal properties of Pigeon pea (*Cajanus cajan*) as related to its processing and utilization. Proc. NIAE 23: 297 – 304.

Ward, J. A. (1976). Processing high oil content seeds in continuous press. J. Am. Oil Chemists Soc. 53(6): 261 – 264.

Wright, F. S. and Splinter, W. E. (1968). Mechanical behaviour of sweet potatoes under slow loading and impact loading. Trans ASAE 11(6): 765 – 770.

Wu, A. and Chang, W. H. (1990). Influence of precooking on the firmness and pectic substances of three stem vegetables. J. Food Sci. and Tech. 25: 558 – 565.

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DEVELOPMENT OF AN OIL PALM FRUIT STRIPPER

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ABSTRACT

Palm fruit stripping operation determines to a great extent, the yield and quality of palm oil. I most small and medium scale palm fruit processors, stripping of fruit is still carried out through hand-picking which is time consuming and tedious. A hand-operated stripper was designed to solve the problem. The evaluation of the machine was carried out using a 2^3 experimental design. The factors considered were sterilization time (60 and 90 mins), angle of inclination of stripper (0^0 and 10^0) and size of cut bunch (Spikelet and quarter) the machine was observed to have a maximum efficiency of 70. 06 % at a sterilization time of 90mins at 0° angle of inclination, and using spikelets. The throughput of the machine was found to be 0.655 ton/hr.

KEYWORDS

Oil palm fruit, stripping method, efficiency, oil yield, oil quality.

1. INTRODUCTION

The oil palm (Elaeis Guineenis) is native to West Africa and has always been a source of dietary fat for the inhabitants of this region. The two primary products from the tree are palm oil and palm kernel from which different products (of immense use domestically and industrially) are derived.

Processing of the oil palm fruit to obtain palm oil and palm kernel involves a series of physical separations which can be classified into five operations viz : fruit sterilization, loosening/stripping, digestion, oil expression or extraction and oil clarification (Babatunde *et al* 1988, Badmus, 1991). The level of technology applied to palm fruit processing varies (though each encompasses the five basic operation listed above), spanning from the crude and inefficient traditional methods that give oil of low quality to the fully automated modern mills with high handling capacity and with high extraction efficiency and high oil quality (Owolarafe, 1999). However, of total yearly production of about 8 million tonnes, 77% is handled by small-scale processors, while the rest 23% is processed by the industrial mills (Owolarafe, 1999).

Fruit sterilization is a heat rendering and moisture conditioning operation that inactivate lypolytic enzymes in fruit (which hydrolyses the palm oil into fatty acids and glycerol), loosens the fruit from the stalks or spikes; and soften the mesocarp tissue to ease oil extraction (Owolarafe *et al* 2001). These objectives are accomplished when palm fruits are sterilized for about one and a half hours (Babatunde 1987 and Owolarafe et al 2001). Sterilizer have been made in different versions to suit the different levels of palm fruit processing technology

Fruits stripping involves the removal of the fruits from the bunches or spikes. In the traditional method it is achieved manually by hand picking or beating with sticks which is labour intensive and time consuming. Fermentation of fresh fruit bunch (FFB) aids the fruit loosening but result in poor palm oil quality. Devices for fruit stripping are common in large mills (Taiwo *et al* 2000).

The yield of oil per FFB however is influenced mostly by the quantity of fruits recovered from the stripping operation which depends on the size of fruit material processed. Babatunde (1988) reported that processing spikelets as against fruit bunch increase fruit recovery and hence oil yield from processed

fruit bunches. A recent survey conducted by Taiwo *et al* (2000) revealed that most processors who are majorly of small-scale still adopt the handpicking method for fruit loosening. This operation which is labour intensive is not only of low *through put* but causes delay in fruit processing which results in low oil quality. Therefore a mechanical device that achieves stripping of fruits from spikelets and replaces the traditional method (fermentation of spikelets and handpicking) will not only increase oil yield but reduces labour requirement and improve oil quality. This study aimed at designing and evaluation of such device.

2. MATERIALS AND METHOD

2.1 Design of the stripper

The design of the stripper is based on impact force that is expected to knock off the fruits from their points of attachment to the spikes whose bonds with the spikes must have been weakened after sterilization. The machine is also expected to separate the spikes from the fruits. To achieve this, the following are the components of the machine as designed.

(a) The shaft: is made of a 1020mm long galvanized pipe (10mm diameter) with 200mm long solid shaft welded to it on both ends (No 5 in Fig. 1). Along the length of the pipe are welded six, 50mm flat bar (equispaced), each spanning the full length of the pipe. Attached to three of the alternate bars are sets of beater arm made of 280mm long 5/8" rods (ten pieces). They are equispaced with 50mm offset at both ends. The shaft is mounted on two ball bearings and bearing housing are fixed to the machine frame.

(b) The drum (No 7 in Fig. 1): Which is 1000mm long and 700mm diameter is made of lengths of metal rods (27 pieces) and flat bars (9 pieces) welded longitudinally to two circular bent 50mm flat bars at the ends. The rods are spaced in a way that they form a sieve that allows for the passage of the fruits alone. This sieve size was determined by finding the average size of the fruits taking into consideration the major and minor diameters of the fruit. Welded to three of the flat bars, along its length are sets of nine, 100mm long rods that serve as counter rods. They are equispaced and at 9mm offset from both ends of the drum. Centrally located at the extreme ends of the drum (on the outside) on each side, is a 40mm flat bar with a 15mm bolt hole for mounting the drum to the frame.

(c) The Barrel (No 9 in Fig. 1): It encloses the rotating cylindrical cage and the shaft. It has an upper part (cover) and a lower part. The upper part is attached to the frame by means of hinges. It has a handle made of a 20mm hollow pipe, and located on the side at the extreme left end is the feeding hopper. The lower part is sloped at an angle equal to the angle of repose of the fruit for the stripped fruit to discharge and the discharge chute is 260mm x 300mm (length and breadth).

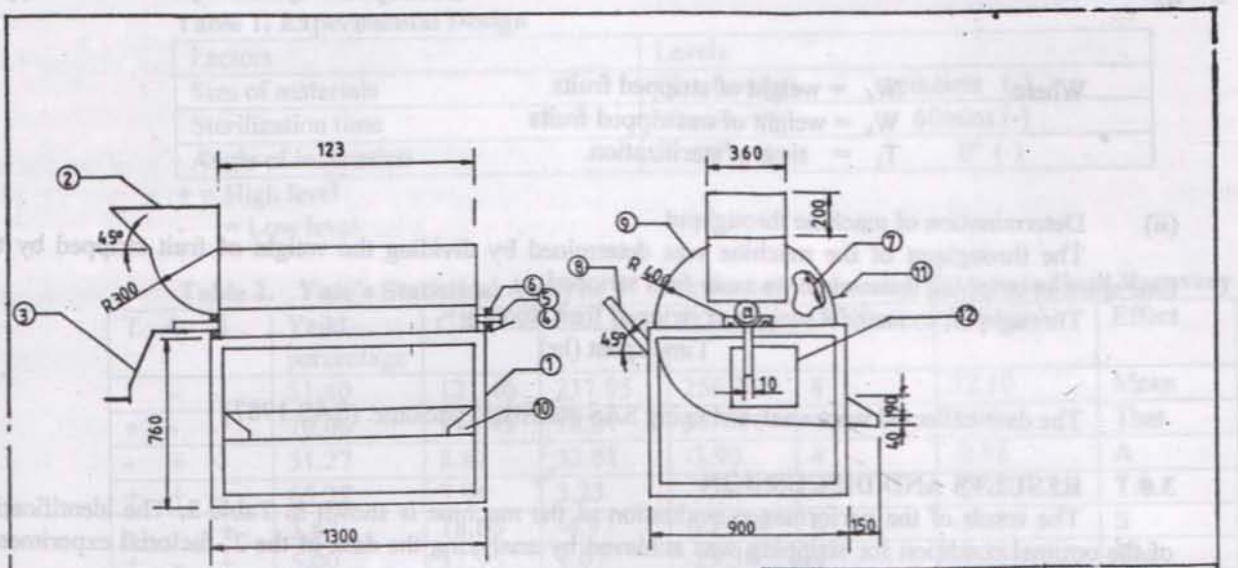
(d) The Handle (No 3 in Fig. 1): is constructed from a 40mm flat bar of 40mm width and 3mm thickness and is attached to the left end of the shaft to drive the shaft.

(e) The Frame (No 1 in Fig. 1): This is box-shape (1300mm long, 900mm wide and 760mm high) made of a 50mmx50mm angle iron.

Plate 1 shows the picture of the machine.

The assemblage of the machine is very simple. The shaft is placed inside the drum, and then the top of the barrel is opened, and the cage and shaft unit is placed in it and coupled to the frame by means of bolts and nuts. Fig, 1 shows the diagram of the machine. Three persons operate the stripper conveniently. One will be feeding it through the hopper, another will be turning the lever while the third person will be collecting the fruit.

The quarters/spikelets are fed through the hopper into the stripper, whose shaft is rotated by an operator using the handle. Then the stripper is continuously fed as the handle is turned. As the shaft continues to rotate the beater rods beat the quarters/spikelets. This action causes the fruit to stripped. The stripped fruits are then collected at the sloped bottom of the barrel while the empty quarters/spikelets are discharged through the outlet at the side of the barrel.



Item	No.	Name	Materials	Specification
1	1	Frame	Mild steel	50mm×50mm angle bar
2	1	Hopper	Mild steel	
3	1	Handle	Mild steel	
4		Bolts & Nuts	Mild steel	15mm bolts
5	1	Shaft	Mild steel	
6	2	Bearing	Mild steel	
7	1	Drum	" "	
8	1	Barrel cover support	" "	50mm×50mm angle bar
9	1	Barrel	" "	
10	1	Fruit outlet	" "	
11	1	Barrel cover handle	" "	
12	1	Residue outlet	" "	

Fig. 1 : Diagram showing components of the stripper

2.2 Performance Evaluation.

2.2.1 Material Collection

Fresh fruit, bunches was collected from the Teaching and Research Farm of the Obafemi Awolowo University, Ile-Ife.

2.2.2 Experimental Design

Based on preliminary experimental runs and information from literature, a 2^3 factorial design as shown in Table 1 was considered appropriate. The factors investigated are sterilization time, size of cut bunch and angle of inclination of the machine.

Guided by the work of Babatunde (1987) the level of sterilization time was set at 60mins and 90 mins. The size of the bunch used were quarters and spikelets while the angle of inclination was 0^0 and 10^0 based on preliminary experimental run.

2.2.3 Experimental run

The fresh fruit bunches were cut into spikelets and quarters using a steel-axe, which were then sterilized in batches using the electric sterilizing unit, under a time variation of 60 mins and 90 mins.

10kg of the sterilized samples was then stripped at 0^0 and 10^0 inclinations. The weight of stripped fruit and un-stripped fruit, and the time for stripping were noted.

2.2.4 Measured Output Parameters

(i) Determination of recovery percentage: This was done by dividing the weight of stripped fruit by the total weight of fruit in the sterilized spikelet and multiplying by 100.

$$\text{Fruit recovery (\%)} = \frac{W}{W_s + W_h} \times 100 \text{ at } T_i$$

Where W_s = weight of stripped fruits
W_h = weight of unstripped fruits
T_i = time of sterilization.

(ii) Determination of machine throughput

The throughput of the machine was determined by dividing the weight of fruit stripped by the time spent in stripping them when no more fruit stripped.

$$\text{Throughput, tonne/hr} = \frac{\text{weight of stripped fruit (tonne)}}{\text{Time spent (hr)}}$$

The data collected were analysed using SAS statistical package. (SAS 1987)

3.0 RESULTS AND DISCUSSION

The result of the performance evaluation of the machine is shown in Table 2. The identification of the optimal condition for stripping was achieved by analyzing the data of the 2^3 factorial experimental designs.

Table 2 shows the percentage of fruit stripped at different combination of size of quarters sterilization time, and angle of inclination. Increasing the sterilization time generally led to an increase in yield of fruit stripped. This is due to the fact that increase in sterilization time leads to more weakening of the bond between the fruit and the stalk. This is in agreement with the work of Babatunde (1987). Increase in sterilization time was observed to increase fruit recovery.

Reduction of the angle of inclination in the range used, led to an increase in fruit stripped from spikelets, and a decrease in fruit stripped for quarters. This was due to the passage of more unstripped spikelets through the outlet for empty spikelets, when the angle of inclination was at 10^0. This can be attributed to inadequate residence time for the stripping operation to get completed. For the quarters the increase in angle led to more of the quarters entering into the drum a little further due to clogging on the first feed of one piece of the quarters.

The increase in size from spikelets to quarters led to a low yield of fruit stripped as a result of clogging inside the drum caused by the quarter staying between two counter arms thereby disallowing for the passage of the beater arm after beating once. Reversing the rotation and the impact of the fruit on falling however resulted in yield increase.

Separate and interactive effect of the factors as analysed using Yate's Algorithm (Table 3) shows that the effect of sterilization time, the interactive effect of angle of inclination and size of cut, and the interactive effect of the three factors (sterilization time, angle of inclination and size of cut) are positive while all other effects are negative. Further analysis using (SAS, 1987) shows that sterilization time and bunch cut size are significant at 95% and 99% respectively.

From Table 2, the highest yield was obtained at sterilization of spikelets fo. 90 mins and machine inclined at 0^0.

Based on the results obtained above, the throughput of the machine was determined by stripping a 10kg of spikelets sterilized at 90mins with the machine at an angle of 0^0. The time taken was 55secs.

$$\text{Throughput} = \frac{10 \times 3600}{55} = 654.54\text{kg/hror.}0.655\text{tonne/hr}$$

The stripping efficiency of the machine was also found to be 70%.

CONCLUSION

Stripping of palm fruit in small-scale palm fruit processing is still done using the traditional-fermentation-and-handpicking method Apart from being a tedious operation, the technique results in poor oil quality. The design of a palm fruit stripper reported in this study aimed at solving the problem. With the result of evaluation of the machine, it is observed to be suitable for small-scale processors (and there

is room to improve on the machine). If incorporated into the processing operation it will enhance the productivity of the processors.

Table 1. Experimental Design

Factors	Levels	
Size of materials	Quarters (+)	spikelets (-)
Sterilization time	90mins (+)	60mins (-)
Angle of inclination	10° (+)	0° (-)

+ = High level
- = Low level

Table 2. Yate's Statistical Analysis of the effect of Processing Factors in Fruit Recovery.

T A S	Yeild percentage	C1	C2	C3	Divisor	Estimate	Effect
- - -	51.40	121.46	237.95	256.76	8	32.10	Mean
+ - -	70.06	116.49	18.81	35.84	4	8.96	That
- + -	51.27	8.87	32.61	-3.90	4	-0.98	A
+ + -	65.22	9.94	3.23	-3.74	4	-0.94	TA
- - +	3,87	18.66	-4.97	-219.14	4	-54.79	S
+ - +	5.00	13.95	1.07	-29.38	4	-7.35	That
- + +	3,92	1.13	-4.71	6.04	4	1.4	AS
+ + +	6,02	2.10	0.97	5.68	4	1.42	TAS

T = Sterilization time
A = Angle of inclination
S = Size of material
$C_1, C_2 C_3$ are constants.

Table 3. SAS Statistical Analysis of the Effect of the Factors On Fruit Recovery

Source	DF	ANOVA SS	Mean Square	F Value	P > F
Model	6	6293.98217501	1048.99702917	286.73	0.0452
Sterilization	6	6293.98217501	6293.98217501	43.23	0.0961*
Angle	1	158.15311250	158.15311250	0.59	0.5819
Size	1	6017.5935125	6017.5935125	1644.82	0.0157**
Sterilization/ angle	1	2.01001250	2.01001250	0.55	0.5939
Angle/size	1	4.16161250	4.16161250	1.14	0.4795
Sterilization/ size	1	109.89031250	109.89031250	30.04	0.1149

* Significant at 95%
** Significant at 99%

REFERENCES

Babatunde, O.O, Ajibola, O.O and Ige, M.T(1988). A modified process for low cost palm oil extraction. Journal of food science and Technology vol. 25, no 2, 67-71.

Babatunde, O.O. (1987) Sterilization and mechanical digestion of oil palm fruit. An unpublished PhD thesis of the Department of Agricultural Engineering, University of Ife, Ile-Ife.

Badmus, G.A. (1991) NIFOR automated small-scale oil palm fruit processing equipment- its need, development and cost effectiveness. In: PORIM International, Palm oil Conference-Chemistry and Technology, pp. 20-31.

Hartley .C.W.S (1988): The oil palm . UK. 3rd Edition Longman group publisher, chapter 14 pp 671-744.

Owolarafe, O.K; Faborode M.O and Ajibola O.O (2002) Comparative evaluation of the digester-screw press and hand-operated hydraulic press. Journal Of Food Engineering, U.K. Vo. 52, 249 – 255.

South Worth, A. (1976) Processing, storage and transport of palm oil and kernels in development in crop science, in oil palm research, ad-corley, R.H.U: Hardon, J.J. and Wood, B.J. Elsevier Science Pub. Co. Amsterdam, 479-497, 1976.

Taiwo, K.A; Owolarafe, O.K; Sanni , L.A; Jeje, J.O; Adeloye, K and Ajibola, O.O. (2000) Technological assessment of palm oil production in Osun and Ondo States of Nigeria. Technovation 20, 215-223.

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TECHNICAL NOTE

LYSIMETRIC EVALUATION OF SEASONAL CROP COEFFICIENTS FOR COWPEA

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ABSTRACT

Lysimetric studies were conducted for two years establish the crop coefficients for cowpea (Vigna Sinensis). A hydraulic weighing lysimeter was utilized for the determination of the crop evaportranspiration (ET_{crop}) at the various stages of crop growth, while the reference crop evapotranspiration (ET_o) was computed from Meteorological data obtained from weather station at the experimental site. The crop coefficients obtained for the study period ranged from 0.2 to 0.9. The implications of these findings to irrigation farming are discussed.

KEYWORDS:

Lysimetric Evaluation, crop coefficient

1.0 INTRODUCTION

Cowpea (Vigna sinensis) is grown as a vegetative crop for fresh pods or as a pulse crop for dry seed. Cowpea grows well in areas with medium rainfall. However, the crop is not recommended for area with excessive rainfall and/or hot weather which may cause flower and pod drop and increase the incidence of diseases. For several years now, much research has been carried out on variety of problems associated with the role of water in aiding growth and enhancing the yields of plants. For example, Ayotamuno et al (2000) outlined some factors that limit crop growth such as soil type, nutrient content and climate, but observed that water has been the principal yield limiting factor. Cowpea production in the humid tropics is beset with problem of low grain yields. This low yield is a function of many factors such as high pest and disease incidences, poor modulation efforts made at increasing cowpea yield; this include breeding for disease resistance and drought tolerance by breeding for early maturity. This is with a view to making them adaptive to different agro-ecological zones in Nigeria. Such varieties would be particularly suitable in areas with unreliable rainfall especially in terms of total amount distribution and duration where crop failure is of the attributed to early ceasation of rains. Therefore, there is the need for proper use of water in the effort to increase food and fibre production under rainfed or irrigated condition. Hence, there is the need for accurate measurement of crop water use rate so that water can be justifiably applied to the crop at a given point in time.

In order to determine the amount of water required at the critical stages of crop growth, a clear knowledge of crop water requirement is essential. One of the practical methods for measuring crop water use rate is the use of lysimeter, which is an indispensable tool for the study of soil-water-plant relationship. It also offers a good opportunity for the planning and operation of irrigation schemes and on-farm water management practices. Allen et al (1994) and Nwa (1994) verified the claim that the determination of crop coefficients at various stages of crop growth will ultimately help to determine the actual crop water requirement at various stages of growth.

Crop coefficient is defined as the evapotranspiraiton of a disease – free crop growing in large field under optimum soil water and fertility conditions (FAO, 1986). Crop coefficients are climate – specific. Available coefficients from literature indicate that they were established mainly in developed countries with different weather condition, which are usually at variance with our local conditions. Therefore, there is a felt-need to develop local crop coefficients instead of using assumed and generalized values for local irrigation practices. this need is achievable through the use of a standard hydraulic weighing lysimeter already developed at National Centre for agricultural Mechanization, NCAM, Ilorin. This could then be used to validate the crop water requirement for the different agro-ecological zones of Nigeria. A systematic investigation that attempts to assemble the various crop coefficients for various agro-ecological zones of Nigeria, will be a great contribution to the food production effort in the country. This is achievable in the sense that there would be available crop water use data to practise irrigation for any crop especially during the off-season planting period.

The estimated crop evapotranspiration value for cowpea can be used on daily, decade and monthly basis for the farmers as well as researchers who are practicing irrigation in order to give them good yield. It is also applicable during the period of drought in the rainy season. This could be realized by determining the area of irrigation and the value of evapotranspiration estimated from the lysimeter at any given period of growth to et the volume of water needed for the cropping area to be irrigated.

The specific objectives of this research were to:

(i) estimate the crop evapotranspiration (ET_{crop}) for cowpea,
(ii) compute the Reference crop evapotranspiration (ET_o); and
(iii) determine the crop coefficients for cowpea.

2.0 METHODOLOGY

The experiment was conducted at NCAM, Ilorin, lysimeter research field. Cowpea was planted on $3.24m^2$ – lysimeter surface area as well as on 100m x 100m buffer area around the lysimeter. The soil is sandy clay and the experimental work covered the periods July to October 1999 and August to October 2001.

Measurements of ET_{crop} were taken from the lysimeter by taking daily readings of the change in weight of the lysimeter inner tank. This was possible by determining the amount of water in the inner lysimeter tank after rainfall, while the change in weight of the lysimeter tank was recorded after drainage water was collected and measured from a calibrated drainage collector in the lysimeter compartment (Adeogun et al 1997). Reference crop evapotranspiration (ET_o) is defined as the rate of evapotranspiration from an extensive surface of 8 to 15 cm tall, green grass cover of uniform height actively growing, completely shading the ground and not short of water (Allen et al., 1994), while crop evaportanspiration (ET_{crop}) is defied as the evapotranspiration occurring when water supplies fully meet the requirements of the crop (FAO, 1986).

The computation of ET_o was carried out by taking daily pan data from US class A pan in NCAM meteorological station which corresponded to the same date lysimeter measurements were taken. These data were averaged over ten-day and thirty-day periods chosen to correspond with the same decade and months over which lysimeter readings were taken. The averaged parameter values were used to compute ET_o. The pan evaporation method used is outlined below:

(i) Pan evaporation method (FAO, 1986):

$$ET_o = k_p E_{pan}$$

Where k_p is the pan coefficient (0.7) and E_{pan} is the pan evaporation.

Applying the relationship between ET_{crop} and ET_o, K_c can be computed.

$$K_c = \frac{ET_{crop}}{ET_o}$$

3.0 RESULTS AND DISCUSSION

Tables 1,2,3 and 4 show the estimated values of crop evaporanspiration (ET_{crop}) and crop coefficients (K_c) for cowpea for decades and the months of the study period. The crop evapotranspiration for cowpea through the growing season indicate relatively lower values at the early stages of crop growth. These values increase during the period of rapid growth to a maximum and thereafter declines after maturity.

A short-term fluctuation was experienced during the early growth stages as observed in the kc values for the first three decades of the 1999 growing season. Thereafter a steady increase was maintained up to maturity on the sixth decade during the growth period. The short-term fluctuation during the growing stages is a result of variations in the prevailing weather conditions which was reflected in the sudden increase in E_{pan} as sown in Table 1.

Figure 1 shows the crop coefficient curve of cowpea sing the 1999 decade data. It was observed that the crop coefficient of cowpea increased to a maximum of 0.8 on the sixth decade and then declined to 0.3 on the tenth decade, while an increase was observed from the first decade to the sixth decade during the 2001 growing season (Fig 2). The implication of this result is that the water use for cowpea is critical on the sixth decade of planting (during the see formation period) and any shortage of water for the crop at this critical period may result in poor yield. Therefore in the absence of rainfall at this stage of growth, supplemental irrigation should be applied for enhanced growth and yield.

The values of crop coefficients (Kc) obtained ranged from 0.2 to 0.9 at different stages of growth. The variation in these values of re-establishes the fact that crop coefficients vary with the stage of crop growth, and is influenced by the prevailing weather conditions such as rainfall, wind speed, temperature and relative humidity at any given period of time.

4.0 CONCLUSION AND RECOMMENDATION

The problem of lack of information on the proper management of crop water requirement relationship has resulted in inefficient use of irrigation facilities in various agro-ecological zones of Nigeria. This research was however geared towards establishing crop coefficients for crops in Ilorin area using cowpea as the test crop. The most important achievement of this work is that the determination of consumptive use of crops has been made easy by measuring ET_{crop} of any given crop by the use of the hydraulic weighing lysimeter at NCAM research field. This information can be used to practise irrigation of the crop (cowpea) during off-season planting. However, it is recommended that a standard irrigation system be established at NCAM for research activities in the centre, especially during the dry season. This will help to carry out the establishment of crop coefficients for the entire year as opposed to the conventional growing season used in this study.

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REFERENCES

Adeogun, E.O, E.U., Nwa; H.L. Musa and F.I. Idike (1997). Design, Construction, Installation and Calibration of a Hydraulic Weighing Lysimeter at NCAM, Ilorin. Journal of Agricultural Engineering and Technology, 5: 37-45.

Allen, R.G.; Smith, M; Pereita, L.S. and Perrier, A. (1994). An Update for the calculation of Reference Evapotranspiration ICID Bulletin. Vol 43(2): 1-92.

Ayotamuno, M.J; S.C. Teme; N.O. Isirimar; A.J. Akor; E.W.U. Essiet and F.I Idike (2000). Relating Corn yield to water Use during the Dry Season in Port Harcourt Area, Nigeria. Journal of Agricultural Mechanization in Asia, African and Latin America. Vol. 31 (4): 47 – 51.

FAO, Food and Agricultural Organization of the untied Nations (1986). Yield response to water. FAO Irrigation and drainage paper no 33:1-28

Ngundo, B.W., and D. Taylor (1974). Effects of Meliodogyne Sp. On bean yield in Kenya. Plant Dia. Reptr. 58: 1028 – 1033.

Nwa, E.U. (1994). Appropriate irrigation and drainage practices to support the index crops for the various ecological zones of Nigeria. Paper presented at the National Symposium on water resources and rural development, Kano State House of Assembly, 5-11 June 1994.

Table 1. Decade values of E_{pan}, ET_o, ET_{crop} and Kc for 1999 cropping season

Decade	E_{pan}	ET_o	ET_{crop}	Kc
1	41.92	29.34	7.8	0.3
2	49.15	34.4	8.34	0.2
3	40.12	28.1	11.34	0.4
4	35	24.5	15.22	0.6
5	33	23.1	18	0.7
6	42.2	29.54	22.53	0.8
7	46	32.2	20.76	0.7
8	44	30.8	16.8	0.5
9	44	30.8	14.81	0.4
10	58	40.6	13.91	0.3

Table 2: Monthly values of E_{pan}, ET_o ET_{crop} and Kc for 1999 cropping season

Month	E_{pan}	$E'T_o$	ET_{crop}	Kc
July	125.76	88.03	23.4	0.3
August	124.27	86.99	34.9	0.4
September	121.2	84.84	61.29	0.7
October	146	102.22	45.52	0.4

Table 3: Decade values of E_{pan}, ET_o, ET_{crop} and Kc

Decade	E_{pan}	ET_o	ET_{crop}	Kc
1	23.1	17.33	8.14	0.4
2	33.5	25.13	11.25	0.4
3	32.2	24.15	13.89	0.6
4	34.1	25.58	16.07	0.6
5	37.3	27.98	18.76	0.7
6	30.0	22.5	19.83	0.9
7	45.1	33.83	14.63	0.4
8	50.4	37.8	10.89	0.3
9	65.8	49.35	7.66	0.2

Table 4: Monthly values of E_{pan}, ET_o ET_{crop} and Kc for 2001 cropping season

Month	E_{pan}	ET_o	ET_{crop}	Kc
August	88.8	66.6	33.28	0.5
September	101.4	76.05	54.66	0.7
October	161.3	120.98	33.18	0.3

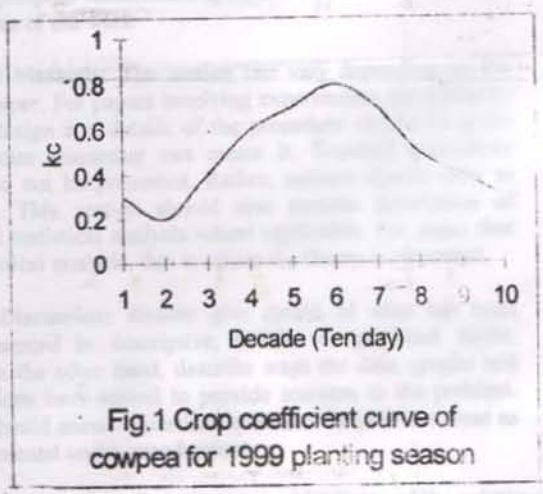

Fig.1 Crop coefficient curve of cowpea for 1999 planting season

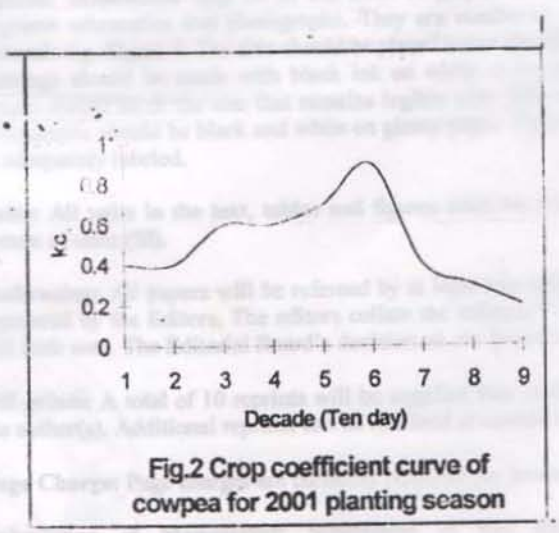

Fig.2 Crop coefficient curve of cowpea for 2001 planting season

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