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MECHANICAL EXPRESSION OF OIL FROM CASTOR SEEDS

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ABSTRACT

The effects of moisture content (6.5% to 12.2% wet basis), heating temperature (60°C to 90°C), heating time (15 minutes to 30 minutes) and applied pressure (15MPa and 10MPa) on the yield of mechanically expressed castor oil were investigated. Oil yield increased with increase in pressure (from 15MPa to 20MPa), heating temperature, heating time and reduction in moisture content within the ranges used in the study. Highest oil yield of 40.4% , corresponding to an expression efficiency of 78.0% (based on seed oil content), was obtained from castor seed sample with moisture content of 6.5% (wet basis) heated at 90°C for 30 minutes and expressed at a pressure of 20MPa. Castor oil was generally found to have a pale yellow colour, refractive index of 1.4774, specific gravity of 0.961. There properties were not affected by processing conditions, within the limits considered in the study.

1. INTRODUCTION

Castor plant (*Recinus commums*) is native to Africa with high adaptability and ability to flourish in areas which are marginal for other crops (Weiss, 1971). This adaptability and the high oil content of the seed (45%) makes the seed to be of considerable economic potential. Oil from the seeds contains 90% recinoleic acid which makes it suitable for diverse uses such as cracked oil, drying oil, wax, lubricating oil and medicinal oil (Weiss, 1971; Bolley, 1959 and Bennet, 1963). The crop is however still grossly under-exploited for oil in Nigeria. The processes used locally are inefficient and the quality of oil produced is low.

In Nigeria, mechanical expression as a method of oil removal from oil seeds is preferred owing to the possibility of using the cake residue (due to its being toxic-free) and its low initial and maintenance costs (Adeeko and Ajibola, 1990). Pre-pressing and pressing conditions such as particle size, moisture content, heating temperature, heating time, applied pressure and duration of pressing have been shown to affect the yield and quality of mechanically expressed oil from oil seeds (Adeeko and Ajibola, 1990; Ajibola *et al.*, 1992; Fashina and Ajibola, 1989). Optimal expression of oil from an oilseed requires the determination of the effects of these processing conditions on the yield and quality of oil expressed.

The characteristics (i.e. quality) of oil from oilseeds are usually determined by certain properties such as peroxide value, fatty acid, iodine value, viscosity and specific gravity of the oil, among others. The peroxide value is a measure of the development of oxidation leading to rancidity. The free fatty acid content and peroxide value are used as quality parameters in commercial transactions, while iodine number expresses the unsaturation level of the oil. Oil viscosity is used in assessing the lubricating properties of oil. Specific gravity is used in assessing the weight of oil in bulk shipments while refractive index is used in identifying adulterated fat (Whiteley, 1951).

This study was undertaken to investigate the effects of some processing conditions on yield and quality of mechanically expressed castor oil. The processing conditions considered are heating temperature, heating time, moisture content, applied pressure and duration of pressing. The physical properties of the oil measured are colour, refractive index and specific gravity.

2. MATERIAL AND METHODS

2.1 The Laboratory Press

The laboratory press used for the expression process (Fig. 1) consists of a lever arm (B) with a drum (A) attached to the end of the arm. Known weights were added to the drum to generate the required pressures. The pressing cylinder (E) made from mild steel pipe is of 4cm diameter and height 8cm. The cylinder was welded to a metal plate (J) serving as a base for the pressing cylinder. A wire gauze wrapped with a piece of cheese cloth was placed inside the cylinder.

The pressing component consists of a metal disc (D), serving as a piston, and a pressing ram attached to it. An hydraulic jack was used to lower and lift the lever arm at the beginning and end of pressing. A measuring cylinder was used to measure the volume of oil expressed over a period of time.

Oil expressed was determined by subtracting the weight of the cake from the weight of the original sample. The percentage of oil removed (oil yield) was based on the weight of the unexpressed sample.

2.2 Test Procedure

Castor seeds (oval in shape) were sourced locally and dehulled manually. For this study, whole shelled seeds were processed. Samples were heating by spreading in a thin layer in a close container placed in a temperature-controlled Gallenkamp oven OV 440V. A thermometer was inserted to verify the oven temperature. Samples were observed to lose heat and as a result the post-heating moisture content values were noted.

observed to lose heat and as a result the post-heating moisture content values were noted.

Samples of 60g mass were used for all the runs in the study. After heating, the samples were wrapped in a cheese cloth and introduced into the pressing cylinder. The oil expressed was collected by a funnel into a graduated cylinder underneath the pressing cylinder.

The factors considered in the study were selected based on review of literature and preliminary laboratory investigations. The moisture content of the seeds were adjusted to obtain samples with moisture contents of 6.5%, 9.5% and 12.2% wet basis which were used in the study. Heating temperatures include 60°C, 70°C, 80°C and 90°C. Heating times of 15, 20, 25 and 30 minutes were used while pressure levels of 15MPa and 20MPa were employed. Application of pressure took 10 minutes for each experiment. For each of the combinations of the levels of factors the experiment was replicated twice.

2.3 Analytical Methods

The moisture content of samples was determined by drying in an oven at 130°C for six hours and then recording the loss in weight as moisture loss (ASAE, 1982). The oil content of the seeds was determined using Soxhlet extraction method (AOAC, 1984). The protein content was determined by a 1030 automatic analyzer incorporating both distilling and titrating units. The ash content of the seeds was determined by ashing 5g of sample in a furnace of 525°C to constant weight (AOAC, 1984).

The refractive index of the oil samples was determined by a table refractometer (Carl Zeiss 74111). The specific gravity was determined in a 10ml gravity bottle. The colour of the oil was determined by using a Munsen Colour Chart.

3. RESULTS AND DISCUSSION

Proximate analysis of the castor seeds shows that it has an oil content of 51.8%, moisture content of 4.1% (wet basis), protein content of 21.0%, crude fibre of 19.9% and ash content of 3.2%. The values of the residual oil content of cake samples were close to the values expected from subtraction of expressed oil from the total oil content of the nut (but always slightly less). The reduction in the observed residual oil when compared with expected values can be attributed to losses in the pressing cylinder and in the wrapping cloth.

3.1 Effects of Processing Factors on Oil Yield

Tables 1 and 2 show the oil yields obtained at the different pre-pressing conditions and applied pressures of 15 and 20MPa respectively. Generally, the response of oil yield to the pre-pressing conditions was similar at the two applied pressures. Oil yield increased with increase in pressure from 15MPa to 20MPa. The increase in oil yield with applied pressure can be attributed to the availability of more force to press the oil out of the seeds.

Table 3 shows the post-heating moisture content under different processing conditions. The post-heating moisture content was dependent on the pre-heating moisture content, heating temperature and heating time. The higher the heating temperature, heating time and pre-heating moisture content, the greater the moisture loss due to heating. These results are similar to those obtained by Fashina and Ajibola (1989) and Ajibola *et al.* (1990) on conophor and melon oil expression respectively.

A statistical package SAS/ STAT™ (SAS, 1987) was used to analyze the effects of the processing conditions on oil yield. Table 4 shows that all the factors considered had significant effects on oil yield from castor seed at the levels considered in the study. Most of the interactions of the factors also had significant effects on the oil yield. The most significant factor is the pre-heating moisture content of the sample. These samples are similar to those obtained by Ajibola *et al.* (1992) in their study on oil expression from sesame seed. For all the heating temperatures considered in the study, the oil yield increased with increase in heating time from 15 to 30 minutes and with decrease in pre-heating moisture content from 12.2 to 6.5% wet basis. The decrease in the oil yield with increase in pre-heating moisture content may be due to the explanation given by Vaughan (1970) that the effect of moisture level on expression efficiency can be related to the development of mucilage (a sticky substance) on the outer walls of the particle and that the addition of more water results in swelling of the mucilage. The mucilage produced a cushioning effect which hinders oil expression.

Similar to the findings of on oil expression from conophor nut (Fashina and Ajibola, 1989), and that of sesame seed (Ajibola *et al.*, 1992), it was found that at the pressure levels considered in the study, the oil yield was dependent on the post-heating moisture content of the sample. Figs. 2 and 3 show the effect of moisture content after heating on oil yield at expression pressure of 15MPa and 20MPa. Each of the figures indicates the data obtained at all the heating temperature and heating time combinations used in the study. Generally, the oil yield increased with decrease in post-heating moisture content up to about 5.5% (wet basis).

Oil yield increased with increase in the heat treatment given to the samples at the two expression pressures. Fig. 4 shows the relationship between the heat treatment, heating temperature and time and oil yield at expression pressure of 15MPa. Increase in heating temperature (from 60°C to 90°C) increased oil yield from 15 to 25 minutes of heating. For samples heated for 30 minutes there was no significant difference in the oil yield at the different temperatures. The increase in oil-yield with heat treatment may be attributed to the achievement of the objectives of heat treatment (coagulation of protein, reduction of viscosity, etc) thereby enabling oil to ooze out while moisture loss also takes place as reported by Fasina and Ajibola (1989) and Ajibola *et al.* (1990, 1992) on conophor, melon and sesame seeds respectively.

Constant oil yield or slightly lower oil yields obtained with increase in heating time at the different temperatures and at expression pressure of 15MPa (Table 3 and Fig. 4) can be explained that increase in heat treatment time accompanied by loss of moisture beyond a certain limit leads to surface hardening of the samples that some of the applied pressure would have to be used in overcoming the hardened surface thereby leaving less pressure for oil expulsion. This result agrees with the findings of Adeeko and Ajibola (1989) on groundnut. They found that increase in heat treatment time beyond 25 minutes led to a decrease in oil yield at temperature of 160°C.

However, by increasing pressure from 15 to 20MPa, oil yield was found to increase at the heating temperatures and heating times considered (Fig. 5). This increase may be attributed to the fact that with increase in pressure, more pressure is available to overcome the hardened surface and at the same time expel the oil. The highest oil yield of 40.4% corresponding to expression efficiency of 78.0% was obtained from a sample with pre-heating moisture content of 6.5% heated at 90°C for 30 minutes to post-heating moisture content of 4.5% and expressed at a pressure of 20MPa.

Table 5 shows some physical properties of the oil obtained. Processing conditions did not have any effects on the physical properties within the limits considered in this study. The values obtained were within the ranges specified in literature (UN, 1974).

4. CONCLUSION

The results of this study revealed that expression of oil from castor seed was affected by processing conditions such as heating temperature, heating time, pre-heating moisture content, post-heating moisture content and applied pressure. The separate interactive effects of these factors were found to significantly affect oil yield.

In general, increase in temperature and heating time from 60 to 90°C and 15 to 30 minutes respectively increased oil yield. The highest oil yield of 40.4% was obtained from samples having preheating moisture content of 6.5%, heated at 90°C for 30 minutes as expressed at 20MPa. This corresponds to an efficiency of 78.0% based on castor seed oil content. Processing conditions used did not affect the colour, specific gravity and refractive index.

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Table 1: **Effects of Heating Temperature, Heating Time and Moisture Content on Oil Yield (%) at Expression Pressure of 15MPa.**

Temperature (°C)	Heating Time (min.)	Moisture Content (% wet basis)	
		6.5	*9.5*
60	15	17.9	3.9
	20	30.3	10.8
	25	36.0	13.3
	30	37.9	20.3
70	15	30.7	9.8
	20	37.0	13.3
	25	38.9	20.0
	30	39.7	20.2
80	15	30.8	15.3
	20	39.0	15.7
	25	40.0	20.9
	30	39.4	2.2
90	15	29.5	13.2
	20	38.0	15.0
	25	37.9	15.2
	30	39.0	15.8

Table 2: **Effects of Heating Temperature, Heating Time and Moisture Content on Oil Yield (%) at Expression Pressure of 20MPa.**

Temperature (°C)	Heating Time (min.)	Moisture Content (% wet basis)		
		6.5	*9.5*	*12.2*
60	15	20.0	10.9	3.1
	20	27.9	13.8	8.0
	25	36.5	13.9	9.4
	30	38.2	14.4	11.9
70	15	31.3	11.3	10.1
	20	34.6	14.7	10.3
	25	37.0	14.9	11.4
	30	39.3	15.0	13.0
80	15	31.8	14.4	9.9
	20	37.1	14.9	11.7
	25	37.8	15.8	12.7
	30	39.8	21.3	14.4
90	15	31.2	10.9	6.9
	20	40.3	16.7	10.9
	25	38.4	20.8	10.6
	30	40.4	22.5	14.2

Standard Error = 0.08.

Table 3: Effects of Pre-Heating, Moisture Content, Temperature and Heating Time on the post-Heating Moisture Content of Castor Seed.

Temperature (°C)	Heating Time (min.)	Moisture Content (% wet basis)		
		6.5	*9.5*	*12.2*
60	15	6.3	9.3	11.7
	20	6.2	9.0	11.2
	25	6.2	8.7	10.4
	30	6.0	8.5	10.0
70	15	6.2	9.3	11.2
	20	5.9	8.3	10.7
	25	5.7	8.3	10.2
	30	5.7	7.9	9.5
80	15	5.8	8.9	9.8
	20	5.8	8.2	10.0
	25	5.6	7.8	9.4
	30	5.4	7.5	8.8
90	15	5.9	8.7	9.4
	20	5.4	7.5	9.5
	25	5.1	7.3	9.0
	30	4.5	7.1	8.4

Standard Error = 0.10.

Table 4: Statistical Analysis of the Effects of Processing Conditions on Oil Yield

Source	Degree of Freedom	Sum of Squares	Mean Square	F Value
Heating Temperature (A)	3	233.372	77.79	84.44 **
Heating Time (B)	3	642.26	214.07	232.37 **
Pre-heating Moisutre Content (C)	2	6500.26	3250.13	3528.00 **
Pressure (D)	1	387.15	387.15	420.25 **
*A * B*	9	50.69	5.63	6.11 **
*A * C*	6	29.02	4.84	5.25 **
*B * C*	3	30.38	10.13	10.99 **
*A * D*	3	14.96	4.99	5.41 **
*B * D*	3	14.96	4.99	5.41 **
*C * D*	1	0.00	0.00	0.00
*A * B * C * D*	24	74.32	3.10	3.36 **

** Significant at 99.9%.

Table 5: Values of Physical Properties of Castor Oil (UN, 1974).

Characteristics	Literature Values	Average Experimental Values	Range of Experimental Values
Specific Gravity	0.958 - 0.969	0.961	0.961 - 0.965
Refractive Index	1.477 - 1.481	1.4774	1.4767 - 1.4778
Colour	Pale yellow	Pale yellow	

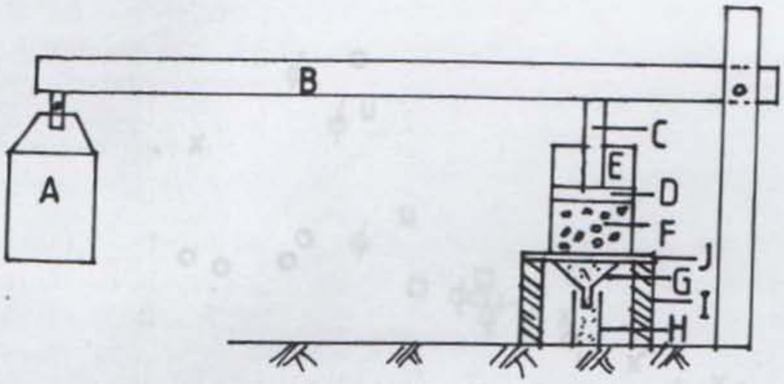

Fig.1 : A Schematic diagram of the laboratory press A, drum B, lever arm; C, press ram; D disc; E, pressing cylinder; F, cake sample; G, funnel; H, measuring cylinder; I, support for pressing cylinder; J thick metal plate.

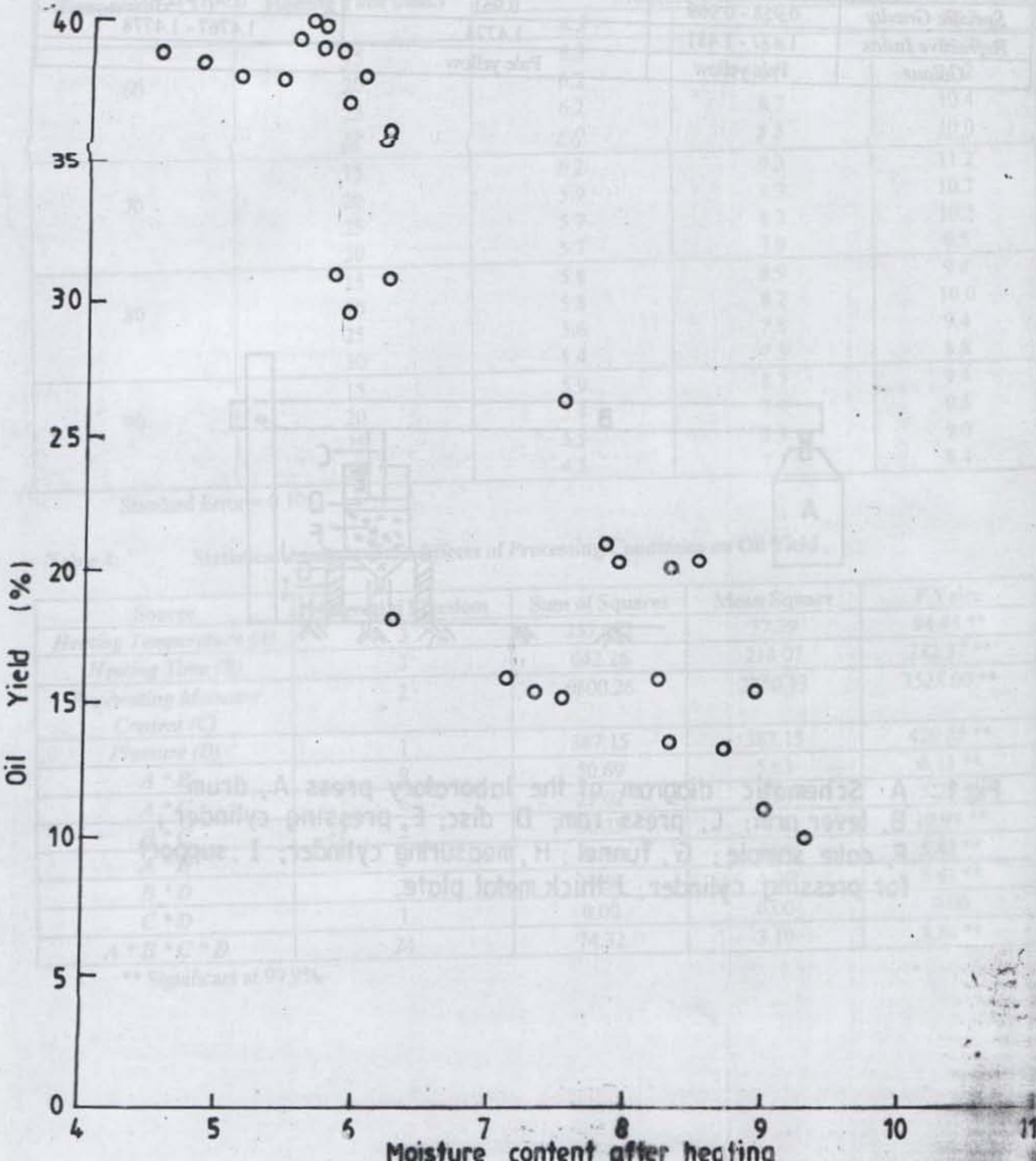

Fig. 2 : Effect of post-heating moisture content on oil yield from castor seed at expression pressure of 15MPa

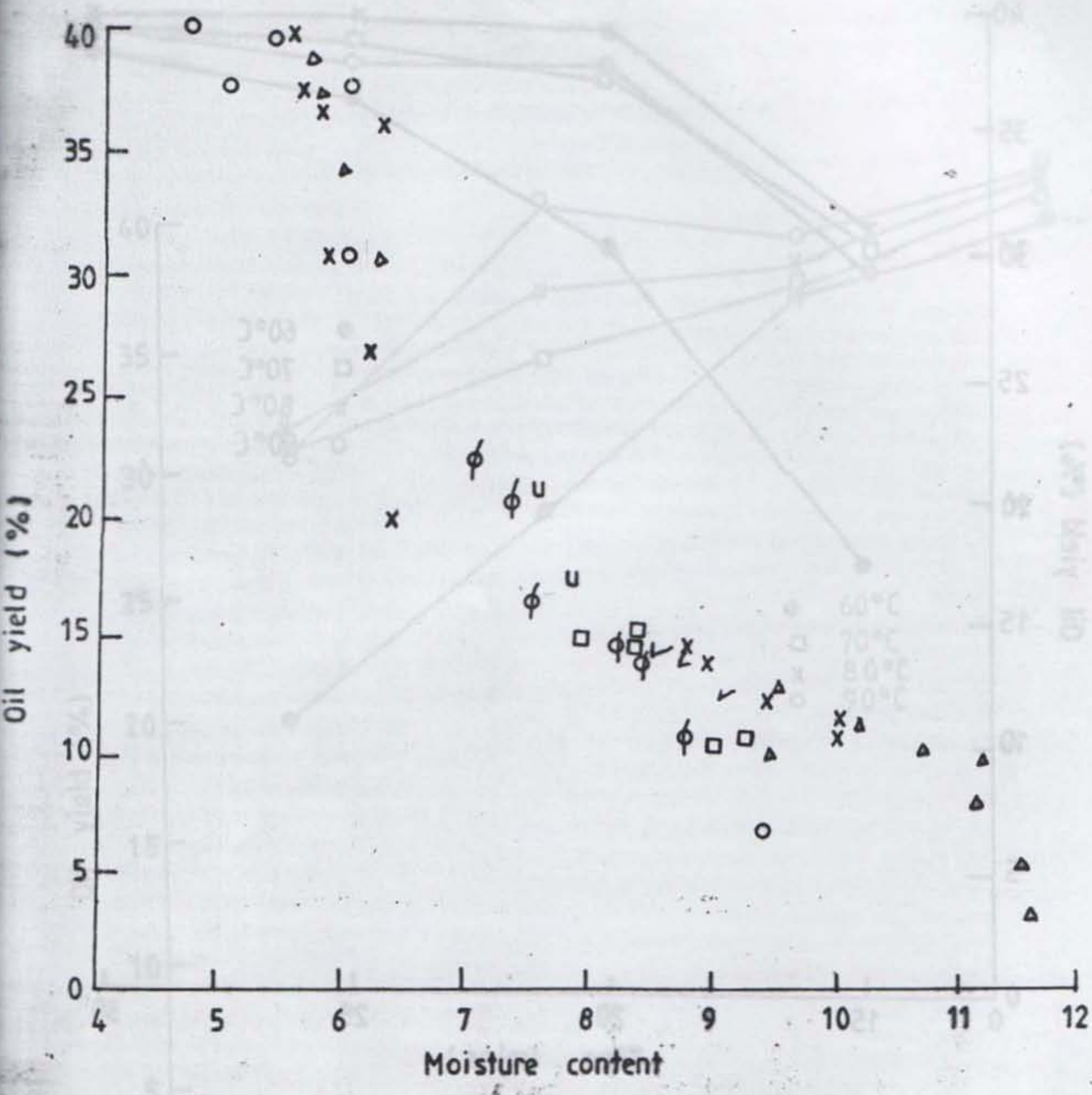

Fig. 3 : Effect of moisture content after heating on oil yield at pressure of 20MPa (12·2% W.B preheating)

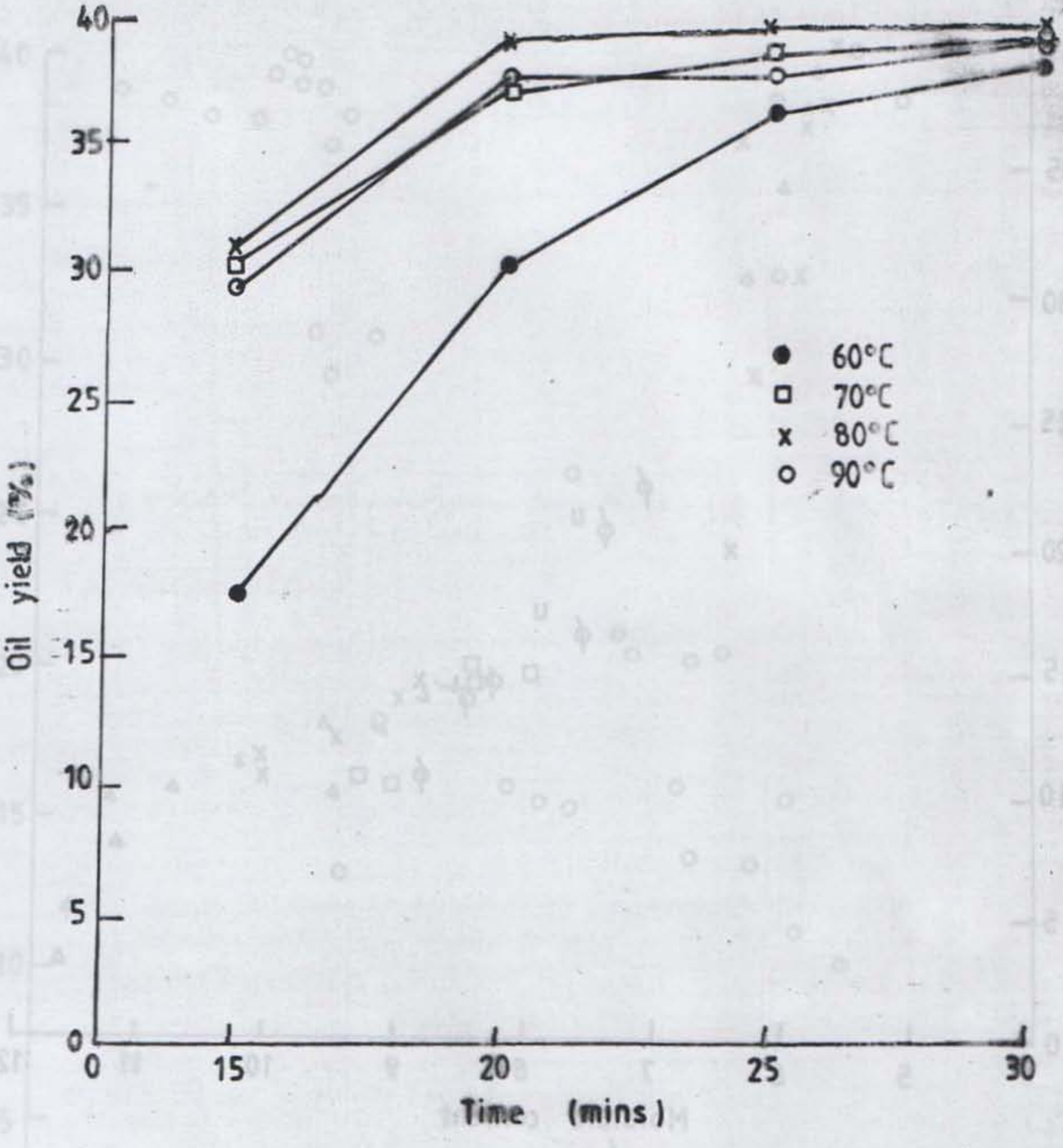

Fig. 4 Effect of heating temperature and time on oil yield at 6.5% moisture content (preheating) at 15 MPa pressure.

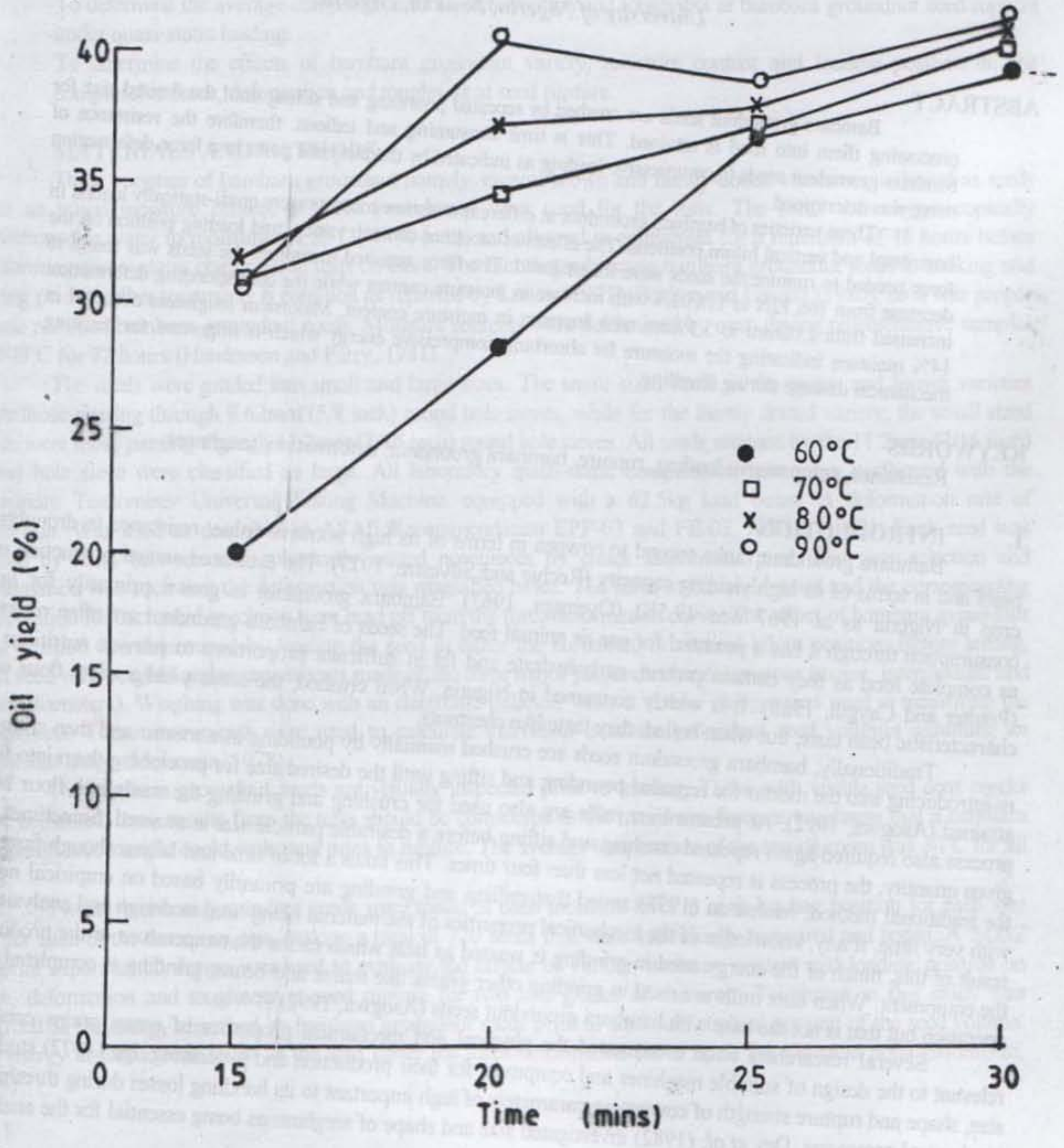

Fig. 5: Effect of heating temperature and time on oil yield at 6.5% moisture content (preheating) at 20MPa pressure.

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MEASUREMENT OF THE RESISTANCE OF BAMBARA GROUNDNUT SEED TO COMPRESSIVE LOADING

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ABSTRACT

Bambara groundnut seeds are crushed by repeated pounding and sifting until the desired size for processing them into food is attained. This is time consuming and tedious, therefore the resistance of bambara groundnut seeds to compressive loading as indicated by the bio-yield point in a force deformation curve was determined.

Three varieties of bambara groundnut at different moisture contents were quasi-statically loaded in horizontal and vertical hilum positions. The effects of moisture content, variety and loading position on the force needed to rupture the seeds were investigated. The force required to rupture the seeds was found to decrease from 166.12N to 118.02N with increase in moisture content while the corresponding deformation increased from 2.08mm to 3.39mm with increase in moisture content. Maximum toughness occurred at 14% moisture indicating the moisture for absorbing compressive energy which is important for resisting mechanical damage during handling.

KEYWORDS

Resistance, compressive loading, rupture, bambara groundnut, deformation, toughness.

1. INTRODUCTION

Bambara groundnut ranks second to cowpea in terms of its high nutritive value, resistance to droughts and pests and in terms of its high yielding capacity (Rechie and Silvestre, 1977). The estimated annual production of the crop in Nigeria as at 1967 was 49.5Kt (Oyenuga, 1967). Bambara groundnut is grown primarily for human consumption through it has a potential for use as animal feed. The seeds of bambara groundnut are often referred to as complete food as they contain protein, carbohydrate and fat in sufficient proportions to provide nutritious food (Poulter and Caygill, 1980). It is widely consumed in Nigeria. When crushed, the seeds yield a white flour with a characteristic bean taste, but when boiled, they taste like chestnuts.

Traditionally, bambara groundnut seeds are crushed manually by pounding in a mortar and then sifting and re-introducing into the mortar for repeated pounding and sifting until the desired size for processing them into food is attained (Asogwa, 1992). At present burr mills are also used for crushing and grinding the seeds into flour but the process also required again repeated crushing and sifting before a desirable particle size is attained. Sometimes, for a given quantity, the process is repeated not less than four times. This takes a lot of time and labour though faster than the traditional method. Mohsenin (1978) stated that milling and grinding are primarily based on empirical methods with very little, if any, knowledge of the mechanical properties of the material being used in design and analysis. As a result of this, much of the energy used in grinding is wasted as heat which raises the temperature of the product and the equipment. When burr mills are used in grinding other grains like maize and beans, grinding is completed in one operation but that is not the case with bambara groundnut seeds (Asogwa, 1992).

Several researchers have investigated the physical and mechanical properties of many grains considered relevant to the design of suitable machines and equipment for their production and processing. Ige (1977) studied the size, shape and rupture strength of cowpea as parameters of high important to its handling losses during threshing and mechanical conveying. Dev *et al.* (1982) investigated size and shape of sorghum as being essential for the analysis of the behaviour of grains during handling, storage and processing. Physical and mechanical properties of corn as related to combine cylinder performance was reported by Anazodo *et al.* (1981). Paulsen (1978) studied the average compressive strength, deformation and toughness at soybean seedcoat rupture under quasi-static loading. Other crops reported on include melon (Makanjuola, 1972), and soybean (hall, 1974). Such similar work appear not to have been done on bambara groundnut seeds. A similar information in its mechanical property would be essential in the design of equipment and system for handling bambara groundnut seeds.

A study of the resistance property of bambara groundnut seeds to compressive loading was then undertaken. The objectives of this study were:

1. To determine the average compressive force, deformation and toughness at bambara groundnut seed rupture under quasi-static loading.
2. To determine the effects of bambara groundnut variety, moisture content and loading position on the compressive force, deformation and toughness at seed rupture.

2. MATERIALS AND METHODS

Three varieties of bambara groundnut namely: cream, brown and faintly-dotted varieties purchased as seeds with an initial moisture content of 11% (wet basis) were used for the tests. The seeds were hygroscopically conditioned in water to moistures of 8, 11, 14% (wb), and allowed to equilibrate for a minimum of 48 hours before performing quaisi-static compression tests on them. The fact that subjecting bambara groundnut seeds to soaking and drying prior to other treatments is common as reported by Lartey (1977), Poulter and Caygill (1980), so it was proper to use rewetted bambara groundnut seeds. Moisture contents were determined by oven drying representative samples at 103°C for 72 hours (Henderson and Perry, 1981).

The seeds were graded into small and large sizes. The small sized seeds in the cream and brown varieties were those passing through 9.62mm (5/8 inch) round hole sieves, while for the faintly dotted variety, the small sized seeds were those passing through 11.2mm (7/16 inch) round hole sieves. All seeds retained by the 11.2mm (7/16 inch) round hole sieve were classified as large. All laboratory quasi-static compression tests were performed with the Monsnato Tensometer Universal Testing Machine, equipped with a 62.5kg load beam. A deformation rate of 3mm/min. Was used as described in ASAE Recommendation EPP-03 and FE-03, ASAE (1973). Each seed was loaded by hand between two spherically seated nosepieces by chuck attachment pins. The gear selection and combination was such that the deformation was magnified twice. The force at bio-yield point and the corresponding deformation for each seed specimen were read off from the force deformation curve. The effect of bambara groundnut seed position was determined by loading the seed in either the horizontal or vertical hilum position. Before testing, each seed was weighed and measurements made of the three major perpendicular dimensions (major, intermediate and minor diameters). Weighing was done with an electronic balance, while a vernier calliper was used in measuring the dimensions. These instruments were used to calculate individual bambara groundnut seed volumes assuming an ellipsoidal shape (Mohsenin, 1978).

The bambara groundnut seeds are visually inspected prior to loading. Those with visible seed coat cracks were not tested, thus, results from the tests should be considered as the maximum force or toughness that a bambara groundnut seed sample could withstand prior to rupture. The average temperature of the testing room was 30°C for all tests.

Twenty bambara groundnut seeds were tested at each moisture level in each loading position for each size and for each of the three varieties, making a total of 720 seeds that were individually measured and tested. A 3x3x2 factorial experimental design was used to evaluate the effects of variety, moisture content and loading position on force, deformation and toughness at seed rupture for two size grades of the crop. Toughness in this study was regarded as the energy absorbed by bambara groundnut seeds prior to seed coat rupture per unit of the seed volume. The energy absorbed was taken as the area under the force deformation curve up to the bio-yield point (Mohsenin, 1978).

The data recorded as means of twenty test samples in each test condition were subjected to analysis of variance (ANOVA) and Duncan's New Multiple Range Test was used to compare the means.

3. RESULTS AND DISCUSSION

All seeds tested typically exhibited a force-deformation curve as shown in Fig. 12. The bio-yield point in the force-deformation curves denote the seed rupture point and this point was determined by a visual decrease in force as deformation increased. The force-deformation curves obtained in this study are similar to those obtained by previous researchers on different agricultural products (Anazodo, 1980; Paulsen, 1978) and those presented in ASAE Standard: ASAE S368.1 (1980). Tables 1, 2 and 3 give a summary of the raw data obtained while the effects of variety, moisture content and loading position on the average force, deformation and toughness are shown in Tables 4, 5 and 6. These effects are discussed below.

3.1 Effect of Variety

The effect of variety on the average force, deformation and toughness at seed rupture is presented in Table 4. The table shows that variety has no significant effect on the average rupture force and toughness at all the moisture levels. Deformation values at rupture of the brown variety is significantly different from others. This may indicate a higher strength property for the brown variety.

3.2 Effect of Moisture Content

The effect of moisture content on average force, deformation and toughness is presented in Table 5. The table shows that the average force and deformation at seed rupture are significantly affected by the seed moisture at P (0.05) level, while seed moisture has no significant effect on toughness. The force required to initiate seed rupture decreased as moisture content increased while the deformation increased with increase in moisture. This contrasting effect may be attributed to the fact that at higher moisture content, the seeds become softened and tend to yield easily to pressure. Also it may be said that grains with lower moisture contents are generally more resistant to breaking under compression than with high moisture contents.

3.3 Effect of Loading Position

The effect of loading position on average force, deformation and toughness is presented in Table 6. The table shows that the average force and toughness are not significantly affected by loading position while the deformation is significantly affected by loading position. This suggests that when the seeds are compressed in either the vertical or horizontal hilum position, they may absorb the same energy.Thus, considerations should not be given to the manner in which bambara groundnut seeds are loading with respect to the compression surfaces, since loading position does not have strong influence on the rupture forces.

4. CONCLUSIONS

1. The average compressive force required to cause bambara groundnut seed rupture decreased as moisture content of the seeds increased from 11 to 14 percent.
2. Bambara groundnut seeds may be loaded regardless of their orientation since loading position has no strong influence on the rupture force.
3. Deformation at seed rupture increases as moisture content increased, suggesting that bambara groundnut at high moistures are softer and more susceptible to breakage.
4. Toughness was not significantly different for all varieties though maximum toughness occurred at 14 percent moisture content.

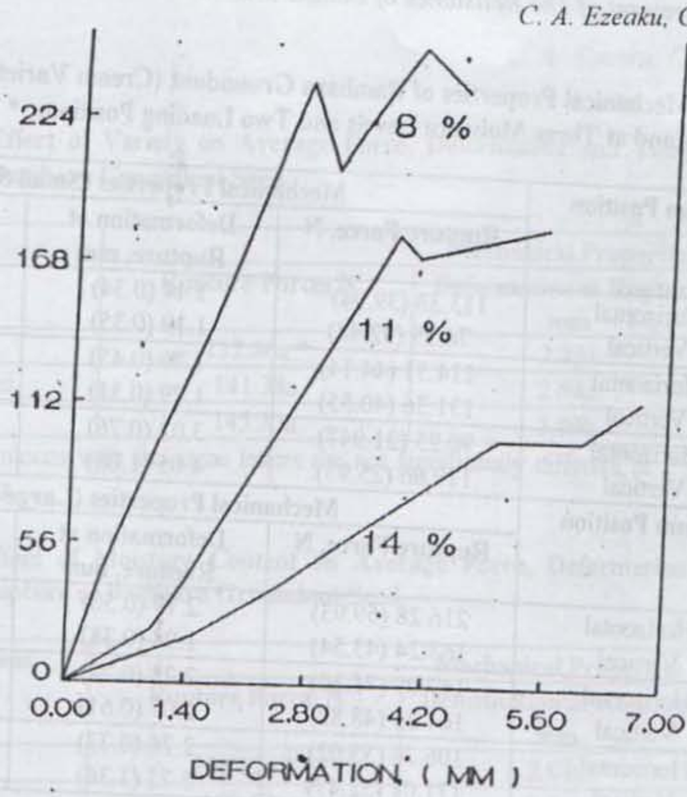

FIG. 1. Typical f - d curves for small size of faintly dotted variety deformed in the vertical hilum position

Table 1: Summary of Mechanical Properties of Bambara Groundnut (Brown Variety) at Seed Rupture for Two Sizes and at Three Moisture Levels and Two Loading Positions. *

Moisture Content (% wb)	Hilum Position	Mechanical Properties (Small Size)		
		Rupture Force, N	Deformation at Rupture, mm	Toughness, mJ/mm^3
8	Horizontal	106.10 (40.62)[SD]	1.68 (0.50)	0.20 (0.11)
	Vertical	151.90 (14.49)	2.45 (0.38)	0.41 (0.16)
11	Horizontal	117.20 (55.88)	3.26 (1.04)	0.43 (0.33)
	Vertical	85.37 (30.33)	3.07 (0.74)	0.29 (0.12)
14	Horizontal	93.79 (29.20)	4.07 (1.02)	0.40 (0.16)
	Vertical	69.87 (28.42)	3.89 (0.93)	0.29 (0.10)
Moisture Content (% wb)	**Hilum Position**	**Mechanical Properties (Large Size)**		
		Rupture Force, N	**Deformation at Rupture, mm**	**Toughness, mJ/mm^3**
8	Horizontal	173.17 (57.99)	2.96 (0.75)	0.33 (0.16)
	Vertical	208.30 (61.72)	3.41 (0.63)	0.45 (0.18)
11	Horizontal	173.92 (55.91)	2.61 (0.64)	0.29 (0.14)
	Vertical	187.25 (57.38)	2.74 (0.65)	0.31 (0.15)
14	Horizontal	188.27 (54.00)	3.61 (0.87)	0.40 (0.16)
	Vertical	178.79 (41.48)	3.56 (0.57)	0.39 (0.11)

* Each value is the mean of 20 test samples

SD Values in parenthesis are standard deviations.

Table 2: Summary of Mechanical Properties of Bambara Groundnut (Cream Variety) at Seed Rupture for Two Sizes and at Three Moisture Levels and Two Loading Positions. *

Moisture Content (% wb)	Hilum Position	Mechanical Properties (Small Size)		
		Rupture Force, N	Deformation at Rupture, mm	Toughness, mJ/mm^3
8	Horizontal	113.33 (39.94)^{SD}	1.44 (0.34)	0.28 (0.15)
	Vertical	76.59 (32.88)	1.19 (0.35)	0.17 (0.12)
11	Horizontal	114.51 (44.14)	1.79 (0.45)	0.28 (0.16)
	Vertical	131.36 (40.55)	1.79 (0.31)	0.31 (0.14)
14	Horizontal	90.25 (21.947)	3.02 (0.76)	0.39 (0.20)
	Vertical	119.66 (25.93)	4.01 (1.06)	0.65 (0.25)
Moisture Content (% wb)	**Hilum Position**	**Mechanical Properties (Large Size)**		
		Rupture Force, N	Deformation at Rupture, mm	Toughness, mJ/mm^3
8	Horizontal	216.28 (59.93)	2.19 (0.50)	0.33 (0.17)
	Vertical	163.24 (43.54)	1.94 (0.38)	0.23 (0.09)
11	Horizontal	187.00 (75.10)	2.23 (0.77)	0.29 (0.17)
	Vertical	164.35 (48.82)	2.07 (0.61)	0.27 (0.18)
14	Horizontal	106.76 (33.02)	2.78 (0.73)	0.21 (0.12)
	Vertical	171.01 (52.47)	3.72 (1.36)	0.44 (0.25)

* Each value is the mean of 20 test samples

^{SD} Values in parenthesis are standard deviations.

Table 3: Summary of Mechanical Properties of Bambara Groundnut (Faintly Dotted Variety) at Seed Rupture for Two Sizes and at Three Moisture Levels and Two Loading Positions. *

Moisture Content (% wb)	Hilum Position	Mechanical Properties (Small Size)		
		Rupture Force, N	Deformation at Rupture, mm	Toughness, mJ/mm^3
8	Horizontal	148.60 (48.82)^{SD}	1.55 (0.37)	0.27 (0.13)
	Vertical	151.93 (67.78)	1.73 (0.55)	0.33 (0.20)
11	Horizontal	123.69 (29.06)	2.32 (0.48)	0.34 (0.16)
	Vertical	144.51 (38.16)	2.87 (0.43)	0.48 (0.18)
14	Horizontal	91.96 (24.76)	2.55 (0.47)	0.27 (0.10)
	Vertical	118.74 (32.09)	3.33 (0.87)	0.48 (0.21)
Moisture Content (% wb)	**Hilum Position**	**Mechanical Properties (Large Size)**		
		Rupture Force, N	Deformation at Rupture, mm	Toughness, mJ/mm^3
8	Horizontal	219.18 (85.40)	1.95 (0.54)	0.23 (0.14)
	Vertical	265.72 (55.01)	2.51 (0.60)	0.35 (0.13)
11	Horizontal	102.23 (32.19)	2.33 (0.57)	0.12 (0.05)
	Vertical	143.67 (72.70)	3.14 (1.13)	0.24 (0.17)
14	Horizontal	91.59 (40.24)	2.71 (0.79)	0.11 (0.06)
	Vertical	95.68 (51.73)	4.44 (1.51)	0.14 (0.09)

* Each value is the mean of 20 test samples

^{SD} Values in parenthesis are standard deviations

Table 4: Effect of Variety on Average Force, Deformation and Toughness at Seedcoat Rupture of Bambara Groundnut Seed.

Variety	Mechanical Properties		
	Rupture Force, N	Deformation at Rupture, mm	Toughness, mJ/mm^3
Cream	137.86a *	2.35a	0.32a
Faintly dotted	141.38a	2.54a	0.28a
Brown	145.33a	3.09b	0.35a

* In each column, means with the same letters are not significantly different at P (0.05) based on Duncan's New Multiple Range Test.

Table 5: Effect of Moisture Content on Average Force, Deformation and Toughness at Seedcoat Rupture of Bambara Groundnut Seed.

Moisture Content	Mechanical Properties		
	Rupture Force, N	Deformation at Rupture, mm	Toughness, mJ/mm^3
8	166.12a *	2.08a	.030a
11	140.42a	2.50b	0.30a
14	118.03b	3.39c	0.35a

* In each column, means with the same letters are not significantly different at P (0.05) based on Duncan's New Multiple Range Test.

Table 6: Effect of Loading Position on Average Force, Deformation and Toughness at Seedcoat Rupture of Bambara Groundnut Seed.

Loading Position	Mechanical Properties		
	Rupture Force, N	Deformation at Rupture, mm	Toughness, mJ/mm^3
Horizontal	136.55a *	2.50a	0.29a
Vertical	146.50a	2.81b	0.35a

* In each column, means with the same letters are not significantly different at P (0.05) based on Duncan's New Multiple Range Test.

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	Vertical	164.35 (48.82)	2.07 (0.61)	0.27 (0.18)
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	Vertical	171.01 (52.47)	3.72 (1.36)	0.44 (0.25)

* Each value is the mean of 20 test samples

^{SD} Values in parenthesis are standard deviations.

Table 3: Summary of Mechanical Properties of Bambara Groundnut (Faintly Dotted Variety) at Seed Rupture for Two Sizes and at Three Moisture Levels and Two Loading Positions. *

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		Rupture Force, N	Deformation at Rupture, mm	Toughness, mJ/mm³
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		Rupture Force, N	**Deformation at Rupture, mm**	**Toughness, mJ/mm³**
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11	Horizontal	102.23 (32.19)	2.33 (0.57)	0.12 (0.05)
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Brown	145.33a	3.09b	0.35a

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Table 5: **Effect of Moisture Content on Average Force, Deformation and Toughness at Seedcoat Rupture of Bambara Groundnut Seed.**

Moisture Content	Mechanical Properties		
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Loading Position	Mechanical Properties		
	Rupture Force, N	Deformation at Rupture, mm	Toughness, mJ/mm^3
Horizontal	136.55a *	2.50a	0.29a
Vertical	146.50a	2.81b	0.35a

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EFFECTS OF IRRADIATION, HOT WATER DIP AND FILM PACKAGING ON THE SHELF LIFE OF PLANTAIN

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ABSTRACT

The effects of low doses of irradiation (0.05-1.0kGy), hot water dip (50°C, 5 mins) and film packaging either singly or in combination, on shelf life and quality of plantain (*Musa paradisiaca*) were investigated.

The 0.1 kGy irradiation dose, 30µm film packaging and hot water dip at 50°C for 5 mins were found to be optimal treatments for the fruit. The 30µm polythene film bag had the most shelf life extension in terms of storage days (23 days) to full yellow ripeness and skin colour scores compared with the other single treatments. The packaging film also had a beneficial effect on the skin and pulp firmness. Combined treatments ($P<0.05$) delayed ripening, microbial growth, and deterioration in fruits and thus extended shelf-life than individual treatments. This is also indicated by the much reduced weight loss. The values for total soluble solids and pH of the plantains were not significantly ($P<0.05$) affected by the different treatments.

Aspergillus niger, Neurospora sitophila and *Candida* species were the microorganisms isolated from plantain fruits that were kept beyond the fully ripened stage. The pathogenicity results showed A niger to cause "black rot" and N. sitophila "brown rot" while the Candida species was not pathogenic to the fruit.

1. INTRODUCTION

Plantain (*Musa paradisiaca*) is an important food item, widely cultivated in the tropics (Karikari, 1971). In Nigeria, both green and ripe plantain fruits are eaten when boiled, roasted, fried, or made into flour, fermented into an alcoholic beverage (Iyare and Ekwukoma, 1992; Abiose and Adedeji, 1994). Despite its dietary importance, plantain production suffers from about 35-100% post-harvest losses at various points in the distribution system of the fruit in Nigeria (Olorunda and Aboaba, 1978). Plantain fruits are usually harvested at a hard and green preclimacteric stage of maturity. Once harvested, the fruit has a very short shelf-life and ripens very quickly with serious losses often occurring (George, 1981; Olorunda and Aworh, 1984). Several methods are available for shelf-life extension of fruits and vegetables. These methods include refrigeration, controlled atmosphere storage, modified atmosphere storage, chemical treatment and irradiation (Falana, 1997). Wrapping or sealing a fruit with a suitable plastic film is reported to reduce moisture loss and create modified atmosphere around the fruit, thereby retarding respiration and delaying ripening (Al-Zaemey et al 1989). However, increased incidence of fungal attack has been reported in film packaged plantain fruits under tropical conditions (Ndubizu, 1976).

The preservation of fresh fruits by irradiation is a relatively recent application. A dose of about 2.0 kGy was suggested for controlling moulds in several species of fruits, however this radiation dose has been found to be higher than what the fruit can tolerate, resulting in fruit softening and rotting due to degradation of pectic substances (IAEA, 1970). The preservative effects of ionizing radiation however have been combined with other treatments such as hot water dip, wrapping in plastic films, chemicals, food surface coating and refrigeration (Campbell-Platt and Gradison, 1990; Russly, 1992).

This present study was undertaken to assess the effects of low irradiation doses, hot water dip and polyethylene packaging on the extension of shelf life of plantain fruits.

2. MATERIALS AND METHODS

2.1 Plantain Fruits

The plantain fruits *Musa paradisiaca* were obtained from Teaching and Research Farm of the Obafemi Awolowo University, Ile-Ife, Nigeria and were sorted in the laboratory for weight (370±20g) uniformity, colour as stage I (green and hard) with the use of Chiquita banana ripening colour chart and for absence of injuries and infections. The fruits were washed with tap water, and air-dried and immediately randomly allocated to different treatments. All the treatments and analyses were carried out in triplicates.

2.2 Individual Treatments of Plantain

Hot water treatment of plantain at 40, 50 and 60°C for 5 minutes to select the optimum heat treatment for the fruit was carried out using a precision hot water bath completed with a shaker for improved water circulation. At the expiration of 5 minutes in the hot water as recommended by Thomas (1986), the fruits were brought out and allowed to air-dry.

A second batch of untreated plantain fruits were placed singly and sealed in 25 µm super microperforated film and 25, 30, 35, 40 µm polyethylene film bags using the Pifco sealing machine. Another batch of fruits were treated with 0.05, 0.1, 0.2, 0.3, 0.4 and 0.5 kGy of gamma rays using the laboratory type of ^{60}Co gamma cell (Gamma Cell 220). The fruits were inserted into the sample chamber or drawer of the cell. After switching on the cell, the button for the upward movement of the sample was operated to bring it out from within the cell. The chamber loaded with the samples was brought into contact with the fixed radiation source, which is a pencil-like ^{60}CO material arranged around the irradiation chamber, by shutting the drawer and pressing the downward movement button on the cell. Irradiation was carried out for a specified time corresponding to the radiation dose required, given the dose rate of the irradiation cell.

The equation for calculating the required exposure time corresponding to a particular radiation dose is given as:

$$t = D/D$$

where t = Time lapse;
D = radiation dose and
D = Dose rate of radiation source.

So given the dose rate of the irradiation sources, the time required for a particular dose of ionizing radiation to be absorbed by a commodity can be calculated (Balogun, 1991).

2.3 Combination Treatments of Plantain

Having established the optimum conditions for the three individual treatments namely hot water dip (50°C/5 mins), plastic film packaging (30µm gauge) and irradiation (0.1kGy), the following combination treatments were investigated:

(i) Hot water dip (50°C/5 mins) combined with irradiation (0.1kGy).
(ii) Hot water dip combined with polyethylene film (30µm gauge) packaging.
(iii) Polyethylene film (30µm gauge) packaging combined with irradiation (0.1kGy).
(iv) The full combination of hot water dip (50°C/5 mins), polyethylene film (30µm gauge) packaging and irradiation (0.1kGy).

Fruits for the different treatments were stored at 27 ± 2°C and 80± 2% RH in a temperature and humidity controlled cabinet (LFEC SFC3, LEEC Ltd., Nottingham, U.K.)

2.4 Measured Variables

The Chiquita banana ripening colour chart (Chiquita Group Ltd., U.K.), was used to assess colour changes in the fruit from Stage 1 to 6 ripeness over the storage period. This was done to establish the optimum conditions for the individual treatments and to observe the effects of the different treatments on the degreening of the plantains.

Forces required to rupture the skin (peel) and the pulp of the plantain fruits in the different treatments were measured using the Stevens Compression Response Analyser CR 1000 (C. Stevens and Son Ltd., Herts England).

For the peel rupture force, four discs of peel tissue (22 mm diameter) were cut from the middle portion of a fruit, and placed one at a time, on a platform containing an 8 mm diameter hole, aligned with a 6 mm cylindrical probe. The maximum force in grammes required to shear a disc out of the larger peel was recorded on the digital display as the probe descended down the peel at a speed of 5 mm/min. and the average force expressed as kilogram force (kg m/s^2).

The pulp rupture force was carried out using the same equipment as for peel except that the cylindrical transverse section (10 mm each), containing both pulp and peel tissue were cut from the fruit using a sharp double bladed knife. The maximum force to rupture pulp was recorded on the digital display as the probe penetrates into the cortex of the slice to expel a plug of the sample out through the 8 mm hole. The average rupture forces also expressed as kg m/s^2.

2.5 Weight Loss, Total Soluble Solids (TSS) and pH

Weight loss in of fruits in the different treatments were obtained by determining the initial weight of each fruit before storage and subsequent weight on each storage day using a Mettler PL 3000 top loading balance (Mettler Instrument AG, CH 8606, Switzerland). The mean weight loss for each treatment was calculated as a percentage of the mean of initial weight.

The juice for the TSS determination was obtained using the method of Wade and Bishop (1978). Fruit pulp (40 g) was homogenised in 200 ml distilled water, with Moulinex blender for 2-3 minutes. The homogenate was centrifuged (1.95g revs/min.) for 20 minutes, using the MSE Centaur 2 Bench-top centrifuge, Fisons, England. Drops (2-3) of the supernatant were placed on a hand held refractometer (Bellingham and Stanley Ltd., Tunbridge Wells, UK), with a direct sucrose calibration of 0-28%, and a sensitivity of 0.5%. The refractometer displays the refractive index on the fruit juice, which multiplied by a dilution factor of 5 gives the % TSS. The supernatant obtained for the TSS was used for the pH determination in a glass electrode pH meter (Kent Industrial Measurement Ltd., England).

2.6 Gaseous Levels in Packages

The levels of carbon dioxide (CO_2) and Oxygen (O_2) gases inside the different film packages were monitored daily over a storage period of a week. Samples of air taken directly from the packages using a needle syringe were injected into the Servomex L.R. Gas Analyser PA 404 and Servomex Oxygen Analyser 574 (Servomex Controls Ltd., Crowborough, Sussex).

2.7 Isolation and Cultivation of Microorganisms

Plantain fruits subjected to irradiation treatment, mild hot water dip, film packaging and their combinations as well as the untreated control were observed for microbial growth and spoilage. Where this was evident, inoculum was obtained aseptically and plated on malt extract agar, potato dextrose agar, corn meal agar and tryptone-glucose extract agar. The first three media were supplemented with 1.0% chloramphenicol for the inhibition of bacteria while the last medium was supplemented with 0.1% cycloheximide to inhibit growth of molds and yeasts. Inoculated plates were incubated at 30°C for 2 days and 5 days for bacteria and fungi respectively. Pure cultures of the isolated colonies were prepared by sub-culturing on media in which they were originally isolated.

2.8 Identification of Isolates

Colony appearance on plates and morphological characteristics served as the basis for the initial classification of the isolates (Kiss, 1984). Further identification was according to Kiss (1984), Lodder (1971), Raper and Fennell (1965) and Barnett and Hunter (1973). The isolates were also confirmed by the International *Mycological Institute, Surrey, England.*

2.9 Back Inoculation of fruits with Isolates

Healthy, fresh, green, hard and disinfected plantain fruits were inoculated with isolates to investigate their ability to infect the healthy fruits and to observe spoilage symptoms of each isolate. The fruits were observed daily for visible signs of microbial growth and deterioration.

3. RESULTS AND DISCUSSION

Plantain fruits subjected to irradiation were observed to tolerate low doses not exceeding 0.2 kGy as higher doses caused skin discoloration and the fruits softened within 3-days (Table 1). Skin browning at higher irradiation doses may be due to increased polyphenoloxidase activity in the treated fruits and the consequent oxidation of the phonolics. It was observed that banana irradiated with 0.3 kGy showed browning presumably due to phenolase which could be responsible for the browning (Thomas & Nair, 1971).

The number of days taken by plantain fruits irradiated at 0.1 kGy, to ripen from green to full yellow colour was significantly different at 0.05 level from that of 0.05, 0.2 kGy and the control (Table 1). Although the colour scores for this batch of fruits and the 0.2 kGy treated fruits were not significantly different at 7 days of storage, they had the most delayed ripening in terms of storage days (12.5 days) to full yellow ripeness. This irradiation dose (0.1 kGy) was therefore considered the optimum dose, for the plantain. Compared with the control and the unpackaged irradiated fruits, film packaging significantly delayed ripening and thus extended shelf life of the plantain fruits (Tables 3 & 2). This is also indicated by the results for the colour scores.

Among the plastic films tested, the 30 microns polyethylene film bag (PB) had the most delayed ripening effect in terms of storage days (23.50 days) to full yellow ripeness and colour score (Table 2). Relative to either irradiation or film packaging alone, the combined treatment of film packaging with either hot water dip, irradiation or both showed further beneficial effects with respect to delayed ripening (Table 3). A combination of film packaging and irradiation was observed to be the best treatment for the extension of shelf life of the plantain fruit, thus suggesting synergistic effects of the two treatments. This agrees with the findings of Campbell-Platt and Grandison (1990) that the preservation effects of ionizing radiations have been reported to be often advantageously enhanced when combined with other treatments such as modified atmosphere packaging (MAP) using plastic films or food coating agents and the application of mild heat treatment.

Firmness in the plantain fruits subjected to the single individual treatments as well as their combinations were not significantly different from each other and the control at the green stage as indicated by the values for the initial rupture force of peel and pulp (Tables 1, 2, and 3). At day 7 however, the polyethylene packaging gave significantly firmer fruits than the control and the other single treatments. This agrees with the findings of Yahia and Gonzalez-Aguilar (1998) who observed that softening in avocado fruit was reduced by packaging in polyethylene films. The magnitude of firmness in the different treatments were in the order of the combined treatments being highest, followed by the polyethylene packaging, irradiation and the untreated control.

Film packaging significantly reduced weight loss in the fruits. Water loss has been implicated in deterioration of banana and plantains as a result of reduction of preclimacteric period (Khan & Mohammed, 1969; Littmann 1972). The creation of modified atmosphere within the package in addition to reducing fruit desiccation, is reported to extend preclimacteric period, thereby delaying ripening in the fruit (Littmann, 1972; Al-Zaemey et. al., 1989). The different gauges of polyethylene film had different permeabilities to oxygen and carbon dioxide. The pattern of development of gaseous concentrations in the film packs of the plantain is typified by a rapid change in the first 1-2 days followed by equilibration of the oxygen and carbon dioxide concentrations, which remained relatively stable for the entire storage life (Figures 1 and 2). Among the gauges tested, the 30 microns polyethylene film bag showed a more ideal and stable gaseous (carbon dioxide and oxygen) composition within the package at equilibrium (Figures 1 and 2). The approximately 5% carbon dioxide and 10% oxygen retention in this package probably retarded respiration while preventing the occurrence of anaerobiosis in the fruit.

The low level of irradiation employed in this study had no significant effect on pH and total soluble solids of the plantains when compared to control fruits at full yellow ripeness. The same was observed for the hot water dip treatment and film packaging either alone or in combination with other treatments values (Table 3).

It was observed that combined treatment delayed microbial deterioration in the plantain fruits than the individual treatments. The microorganisms isolated from the fruits were fungi namely (*Aspergillus niger var Tieghem, Neurospora sitophila* and *Candida* species (Table 4). The isolates were confirmed by the International Mycological Institute, Surrey, England. The pathogenicity results showed A. niger to cause "black rot" and N. sitophila, "brown rot" while the Candida was not found to be pathogenic to the plantain fruit. Though microbial growth was not completely arrested by the different individual treatments and their combinations, however, shelf life was extended significantly for the combined treatments.

4. CONCLUSION

In conclusion, irradiation alone as a preservative technique did not appreciably delay ripening of plantains in this study. However when combined with film packaging, greater delayed ripening and microbial deterioration shelf-life extension was achieved. The packaging film had a beneficial effect on the skin and pulp firmness of the plantain as softening and weight loss were reduced. Thus the use of film packaging could be beneficial in increasing the postharvest life of plantain fruit. The quality of the plantains were found to be acceptable based on measurements of parameters such as weight loss, total solids and pH. The 0.1 kGy irradiation dose, 30□m film packaging and hot water dip at 50°C for 5 minutes were found to be optimal treatments for the fruit. Combination treatment could be employed as a feasible preservative method, and will no doubt help in reducing the post-harvest wastage of plantains.

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Table 1: Effect of Low Dose Irradiation on Selected Physical Parameters of Plantains

Irradiation doses kGy	Colour Scores (7 days)	*Rupture Force of Peel		*Rupture Force of Pulp		No. of days to ripeness
		X1	x2	X1	X2	
0.00	5.5	75.5	40.3	43.9	3.9	10.0
0.05	5.2	75.1	40.8	43.6	4.1	10.8
0.10	4.2	75.2	47.1	42.2	4.4	12.5
0.20	4.0	75.9	45.6	42.3	4.2	11.2
0.3-1.0	blackened within 3 days	ND	ND	ND	ND	ND

ND = Not determined
X1 = Initial Rupture Force at day 1
X2 = Rupture Force at day 7
* = Units in kg m/s^2

Table 2: Effect of Film Packaging on Some Physical Parameters of Plantains

Film Type	Gauge (µm)	Colour Scores (7 days)	*Rupture Force of Peel		*Rupture Force of Pulp		No. of days to ripeness
			X1	x2	X1	X2	
Control	-	5.5	75.5	40.3	43.9	3.9	10.0
Supermicro perforated	25	3.7	77.1	45.5	43.9	26.5	11.5
Polyethylene A	25	3.2	77.0	56.4	45.3	27.1	18.0
Polyethylene B	30	2.5	76.0	58.1	44.9	29.4	23.5
Polyethylene C	35	2.7	76.8	56.5	44.7	23.4	21.5
Polyethylene D	40	3.2	76.1	56.3	ND	ND	20.3

X1 = Initial Rupture Force (Day 1)
X2 = Rupture Force at day 7
* = Units in kg m/s^2
ND = Not determined

Table 3: Extension of Shelf Life and Quality Parameters in Treated Plantains

Film Type	*Rupture Force of Peel		*Rupture Force of Pulp		No. of Days to Ripeness	% Weight Loss	% Tss	pH
	X1	x2	X1	X2				
Control	75.5	40.3	43.9	3.9	10.0	15.9	20.0	4.6
Irradiation (0.1 kGy)	75.2	47.1	42.2	4.4	12.5	13.8	18.8	4.6
Hot water dip (50°C, 5 mins.)	74.8	39.3	40.9	4.6	9.0	14.0	18.1	4.6
Hot water dip + Irradiation	74.0	40.2	39.9	4.8	23.5	1.2	17.8	4.7
Film Packaging B	76.0	58.1	44.9	29.4	23.5	1.3	18.8	4.7
Film Packaging + Hot water dip	74.3	63.1	40.5	32.8	24.1	0.4	18.0	4.7
Film Packaging + Irradiation	74.4	67.4	41.4	38.6	26.1	1.3	17.8	4.7
Film + hot water Dip + Irradiation	74.6	66.7	39.8	37.8	25.4	0.5	17.5	4.7

TSS = Total Soluble Solids
X1 = Initial rupture force at day 1
X2 = Rupture force at day 7
* = Units in kg m/s^2

Table 4: Incidence of Microbial Growth in Treated Plantains

Treatments	A. niger	N. sitophila	Candida
Control	+	+	+
Irradiation (0.1 kGy)	+	+	+
Hot water dip (50°C, 5 mins.)	+	+	+
Film packaging B	+	+	+
Hot water + Irradiation	-	+	+
Hot water + Film B	-	+	+
Film B + Irradiation	+	-	+
Hot water + Film B + Irradiation	-	-	+

+ = Isolated
- = Not isolated

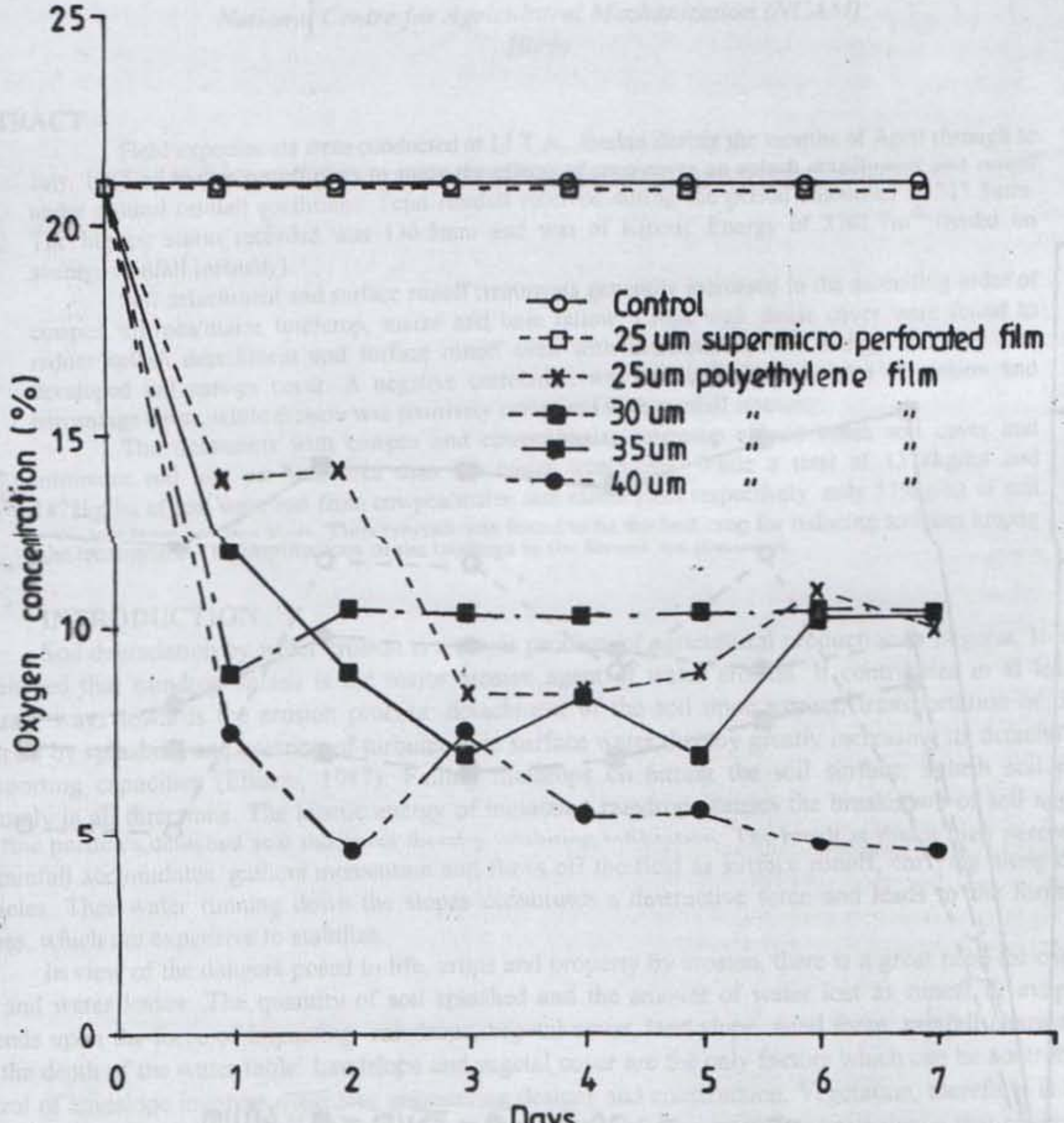

Figure 1 Oxygen concentration around fruits sealed in plastic films of different gauges

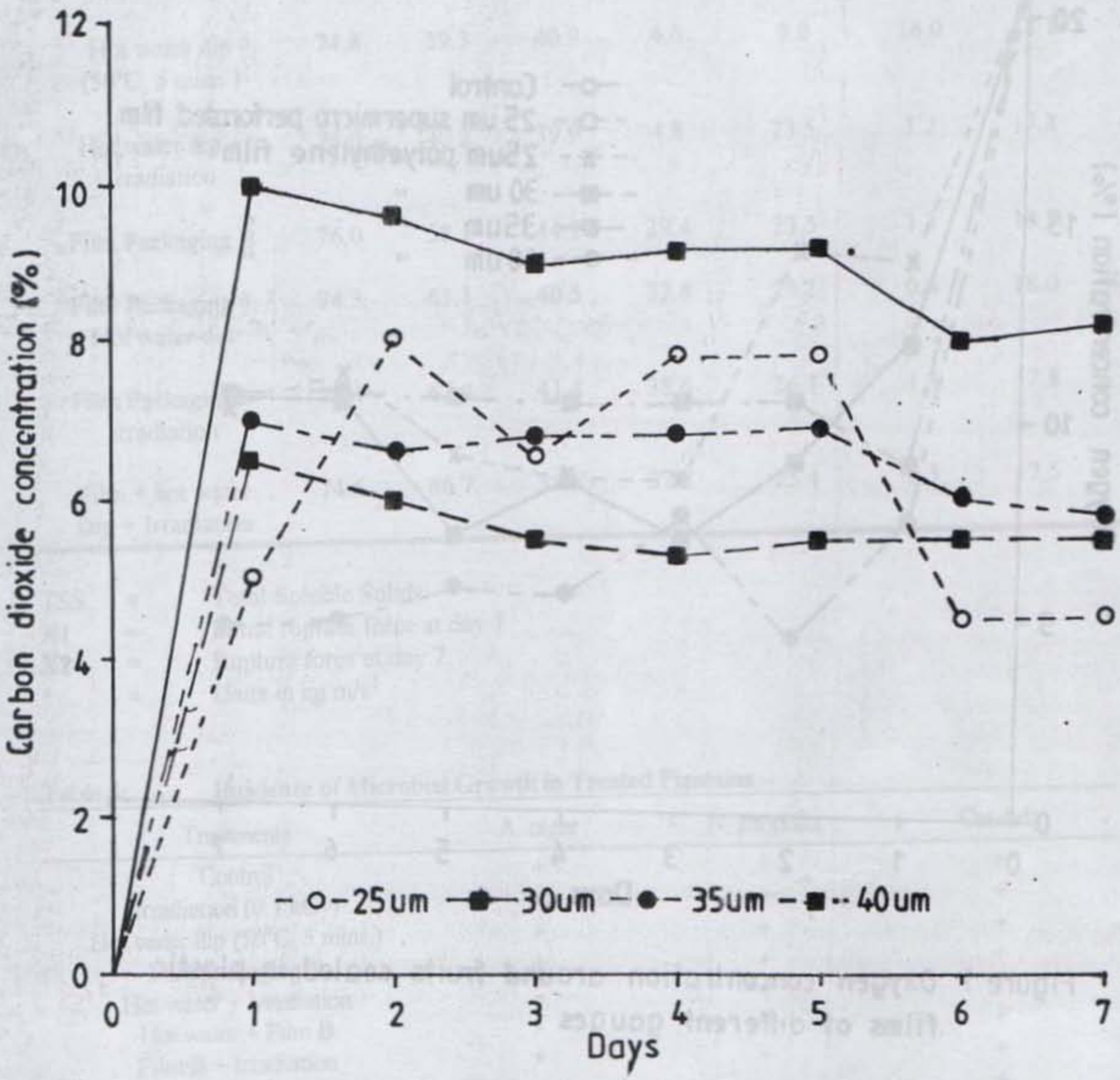

Figure 2 : Carbon dioxide concentration around fruits sealed in polyethylene films of different gauges.

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EFFECT OF COVER CROP ON SPLASH DETACHMENT AND RUNOFF

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ABSTRACT

Field experiments were conducted at I.I.T.A., Ibadan during the months of April through to July, 1985 on twelve runoff plots to study the effects of crop cover on splash detachment and runoff under natural rainfall conditions. Total rainfall received during the period amounted to 513.5mm. The highest storm recorded was 130.5mm and was of Kinetic Energy of 2762.7m^{-2} (based on average rainfall intensity).

Soil detachment and surface runoff treatments generally increased in the ascending order of cowpea, cowpea/maize intercrop, maize and bare fallow. Crops with dense cover were found to reduce splash detachment and surface runoff even with increased rainfall energy and they had developed full canopy cover. A negative correlation was obtained between rates of erosion and percentage cover, while erosion was positively correlated with rainfall intensity.

The treatments with cowpea and cowpea/maize intercrop offered better soil cover and minimum soil loss per unit area than the maize treatments. While a total of 1378kg/ha and 1472kg/ha of soil were lost from cowpea/maize and maize plots respectively, only 559kg/ha of soil were lost from cowpea plots. Thus cowpea was found to be the best crop for reducing soil loss among the treatments. The implications of the findings to the farmer are discussed

1. INTRODUCTION

Soil degradation by water erosion is a major problem of agricultural production in Nigeria. It has been established that raindrop splash is the major erosive agent of water erosion. It contributes in at least three different ways towards the erosion process: detachment of the soil upon impact, transportation of detached particles by splashing and creation of turbulence in surface water thereby greatly increasing its detachment and transporting capacities (Ellison, 1947). Falling raindrops on hitting the soil surface, splash soil particles randomly in all directions. The kinetic energy of impacting raindrops causes the breakdown of soil aggregates and fine particles detached seal the pores thereby inhibiting infiltration. The result is that a high percentage of the rainfall accumulates, gathers momentum and flows off the field as surface runoff, carrying along detached particles. Thee water running down the slopes constitutes a destructive force and leads to the formation of gullies, which are expensive to stabilize.

In view of the dangers posed to life, crops and property by erosion, there is a great need for controlling soil and water losses. The quantity of soil splashed and the amount of water lost as runoff or evaporation, depends upon the force of impacting raindrops, vegetal cover, land slope, wind force, rainfall characteristics, and the depth of the water table. Landslope and vegetal cover are the only factors which can be controlled. The control of landslope involves expensive engineering designs and construction. Vegetation, therefore, is the only controllable factor within the reach of resource poor farmers. Moreover, studies have shown that cover reduces soil erosion more than an other factor in soil management (Akhabedu, 1985; Freebairn and Wockner, 1986; Sallaway et al, 1990).

To achieve complete ground cover is not easy. It may involve mulch materials which are laborious to collect in large quantity and expensive to purchase because they serve as animal feeds also. To minimize cost and save labour, it is suggested that farmers use crops as cover. This can be achieved by employing mono and mixed cropping patterns depending on the crop or crop combinations the farmer wants to grow. In suggesting the use off crops as cover, the question arises as to how much cover is needed for checking the erosive effects of rainfall and so it becomes necessary to test the efficacy of different crops in this regard in order to choose the best among them.

The effect of various crop covers on splash detachment and runoff can be evaluated by measuring the soil and water loss under each crop after storms. This can serve as a guide in planning soil and water conservation measures.

The objectives of this study were to:

1. evaluate splash erosion under sole and mixed cropping; and
2. study rainfall interception by crop cover and its effects on soil detachment and runoff.

2. MATERIALS AND METHODS

The field measurements were carried out on twelve runoff plots each measuring 4.5m X 4m on a natural slope of 10 percent. The plots were established side by side with one meter buffer zone separating them. The edges of the plots were constructed with earth bunds about 30cm high and covered with mulch material. The bunds allow runoff water to concentrate at the bottom end of each plot. At the down slope of each plot is placed a collection system (standard drum). Runoff from each plot passes into the collecting drum through a multi-divisor flume.

The experiment consisted of 4 treatments, namely, control, cowpea (*Vigna unguiculata*), maize (*zea mays*) and cowpea-maize intercrop. The treatments were replicated 3 times in a completely randomized block design. The control consisted of bare soil under fallow with tillage operations up and down the slope. Manual tillage was first carried out, followed by rotavation with the aid of a small capacity (355kW) tractor.

All crops were planted on the 11th of April, 1985. The planting was carried out with a manually operated Jab planter. The row to row plant spacings were, for sole maize, 70cm X 25cm; sole cowpea, 50cm X 25cm and cowpea maize, 50cm X 25cm.

A recording rain gauge, installed at a distance of 100m from the field plots, provided the necessary rainfall data. Soil splash was measured using splash cups designed by the author. Each splash cup is a hollow metal cylinder. The cups were located at the centre of each plot. The cups were pushed into the soil in such a way as to allow a projection of about 1cm above the ground level to prevent runoff water from entering the cups. The mesh was then covered with a 122.5cm diameter filter paper to prevent fine particles trapped into the cup from escaping the mesh.

After each rain event, soil splash trapped into the cup were carefully removed with the filter paper, oven dried and weighed, while a new filter paper was weighed and replaced in the cups. The apparatus can only trap soil particles that ended their trajectory motion within the surface area of the cup. In accord with Morgan (1982), no satisfactory system for field measurement of splash has yet being developed. Runoff measurements were taken after every rainfall. Soil loss through runoff was determined for each treatment. This was achieved by collecting a sample of the runoff after stirring to form a homogeneous suspension, filtering it and the filtrate oven dried at 105°C for 24 hours and weighed.

3. RESULTS AND DISCUSSIONS

3.1 Effect of Crop Cover on Soil Splash

The rainfall distribution, duration and the days on which they were received it presented to Table 1. The average rainfall intensity, the maximum 30-minute intensity and total kinetic energy of each rain based on the method by Hudson (1965) are also shown in Table 1. The mean soil splash for each treatment with respect to corresponding rainfall event is given in Table 2.

The cover rating of each crop gives an idea off its growth rate and its effectiveness in protecting the soil against splash erosion. The inability of the crops to develop enough vegetative cover in their early stages of growth (Fig. 1) led to the very low cover ratings recorded at this stage with resultant high soil splash. There were significant differences in the vegetal cover provided by each cropping system. More cover was provided by cowpea, followed by cowpea/maize intercrop, and maize monocrop in that order. Due to its excellent growth and cover rating values, cowpea gave the lowest soil splash. Maize gave a very poor cover and thus had the maximum soil splash. Even though the cowpea/maize intercrop gave a relatively low soil loss compared with maize, its results were contrary to expectations. This may be attributed to the shading effect of the tall maize crop on cowpea, thereby causing the cowpea to move towards sunlight to effect photosynthesis.

As a result, the spreading nature of cowpea was restricted thereby leading to poor soil coverage. Results of the tests carried out on these field observations show that soil splash from the bare plots and sole maize plots, respectively were significantly higher than those from the sole cowpea and cowpea maize intercrop at 5% level of significance.

Figure 22 shows the relationship between cover and soil splash. The plot depicts a linear but negative relationship. The regression equations of the effect of cover on splash are shown in Table 3. From the negative correlation coefficients for cowpea (-0.2) and cowpea/maize intercrop (-0.53), and the low value of maize (0.3), it can be inferred that soil splash decreases with increase in crop cover. Cowpea with the highest mean cover rating of 77.2% gave the lowest soil splash. Soil splash from cowpea was only 17.8% of the total soil splashed from the cropped plots, while soil splash from maize and cowpea/maize intercrop were 554.5% and 27.6% of the total soil splashed, respectively. However, soil splash from cowpea monocrop and cowpea/maize intercrop were not significantly different. A very important deduction from Figure 2 is that cover ratings below 50% may be critical for erosion control of fragile tropical soils. This premise is predicted on the fact that below this level, soil loss may exceed the tolerance limit (2.0t/ha/yr) for these soils (Lal, 1983). These results agree well with those reported by Freebairn et al (1993).

3.2 Kinetic Energy and Soil Loss

Data on rainfall energy and corresponding total soil loss are presented in Table 4.. Soil loss was the maximum under cultivated fallow throughout the period of experimentation. Bare soils did not provide any protection against the falling raindrops with high energies ranging from $288Jm^{-2}$ to $2763Jm^{-2}$ during the period of this study. As a result, more soil was dislodged by the impacting raindrops and carried away by rebounding splashes and runoff. This seems to bee the major reason for more soil loss on bare plots compared with the cropped plots. It also serves as an indicator for the need to keep lands under crop, especially during the rainy season.

The relationship between Kinetic energy of rainfall and total soil loss with respect to the age of the crops is shown in Fig.3. The figure illustrates that soil loss energy increased with increasing kinetic energy of rainfall for the first 50 days at a fast rate, and at a slower rate thereafter. In some treatments such as cowpea, and cowpea/maize intercrop, soil loss was found to decrease with age after the crops must have established full canopy, even with increased rainfall energy. This proves that with full cover, soil loss can be minimized irrespective of the energy load of the rain. This result tends to support the findings of Morgan (1982) that plant cover appears to be more effective in protecting the soil in the high energy rather than low energy storms.

3.3 Effect of Crop Cover on Runoff Generation

The data presented in Table 5 indicate that runoff from the bare plots was high when compared with those from cropped plots. Because of the absence of vegetation, bare soil was exposed to the damaging actions of falling raindrops. The combined effects of compaction by impacting raindrops and surface sealing by detached fine particles gave rise to low infiltration rate, with resultant high runoff. These observations are consistent with those reported by Kayombo and Lal (1993). Among the treatments, cowpea gave minimum runoff, while that from cowpea/maize was the maximum. The runoff from maize plots was intermediate. Generally, there was no significant difference between runoff from the maize plots and that from the cowpea/maize plots. However, runoff from sole cowpea plots was significantly lower that that from the rest of the plots. Accordingly, cowpea proved to be the best crop with cover adequate to minimize runoff among the treatments.

The quantity of water lost as a result of runoff was found to be proportional to the rainfall received for most times. Cowpea being of a spreading nature, offered better soil coverage. This enable it to intercept the greater percentage of rain falling on the plot; to slow down runoff velocity which created more infiltration opportunity time thereby minimizing runoff loss. Maize was better at intercepting low energy rains than high ones, especially accompanied by high speed wind which led to the lodging of some of the crops, thus exposing the soil to more compaction by impacting raindrops and the high runoff associated with it.

3.4 Implications of Results

1. This field study clearly demonstrated that under natural rainfall conditions, splash detachment and runoff generation depends on a range of factors, including rainfall intensity, duration and interception. This is in agreement with the work done by Poesen (1981) on conditions necessary for runoff generation.
2. Crop cover plays a vital role in raindrop interception, which dissipates the energy of the impacting raindrop, minimizes splash detachment, increases infiltration opportunity time and hence reduces runoff volume.
3. Crops used as cover benefits the farmer in many ways, including reduction in erosion rate which may enhance the fertility of the topsoil, increase soil moisture storage and my culminate in increased yield.

4. CONCLUSION

Evidence is provided to show that splash erosion, which is the main controlling factor in the erosion process, can be considerably reduced with crop cover. Results from field experiment show that the relationships between degree of crop cover and splash detachment were linear and negatively correlated. This means that splash decreases as the crop cover increases. The major reason for this reduction is that crop cover offers natural resistance to raindrop impact.

A good crop cover not only reduces splash erosion, but also decreases runoff velocity, thus increasing time of ponding and infiltration opportunity time thereby reducing runoff erosion. Crops of a spreading nature like cowpea are best for achieving this.

Thee most critical erosion on farmland occurs at those times of the year when the soil is bare. The most inexpensive way to prevent this erosion is to keep the soil covered. Even though soil conservation works is capital intensive, it is the only means of assuring the sustainability of productivity of our farming systems. However, considering the enormous amount of money involved in installing mechanical conservation structures in relation to the economic capacity of our resource-poor farmers, it would be rational to consider good agronomic practices like soil and crop management as viable options for erosion control.

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Table 2. **Soil Splash with respect to rainfall for the treatments**

Date	Rainfall (mm)	Soil Splash (g)			
		Bare	Cowpea	Maize	Cowpea/Maize
17/5/85	27.0	8.2	4.8	5.3	7.4
23/5/85	33.0	4.7	2.7	2.4	3.9
27/5/85	37.2	23.6	8.9	12.9	15.7
1/6/85	40.5	24.3	2.9	6.6	2.2
12/6/85	74.5	35.4	6.2	18.1	6.1
19/6/85	15.5	11.1	0.0	4.9	1.4
26/6/85	79.1	24.9	1.1	13.5	2.3
3/7/85	130.3	50.5	1.5	19.9	4.1
7/7/85	43.2	4.5	0.6	4.3	1.3
Mean	55.6*	20.8[c]*	3.2[a]	9.8[b]	4.9[a]

Table 3. **Regression equations relating soil splash with percent cover ratings**

Treatment	Regression equation	Correlation Coefficient (r)
Cowpea	$Y = 8.3 - 0.07X$	-0.52[a]
Maize	$Y = 5.15 + 0.10X$	0.30[b]*
Cowpea + Maize	$Y = 9.47 - 0.07X$	-0.53[a]

Y = splash (g) X = percent cover rating

Table 4. **Soil loss from the various treatments with respect to rainfall energy**

Date	Rain energy (Jm^{-2})	Total soil loss (kg/ha)			
		Bare	Cowpea	Maize	Cowpea/Maize
17/5/85	475	60	12	21	56
23/5/85	409	77	29	26	17
27/5/85	1344	111	27	93	769
1/6/85	910	1028	17	49	102
12/6/85	1520	2393	95	613	432
26/6/85	1567	243	5	96	61
3/7/85	2763	995	348	422	261
7/7/85	880	383	25	152	109
Cumulative total	9868	5289	559	1417	1378

Table 5. **Water loss as runoff from the various treatments with respect to rainfall amount**

Date	Rainfall (mm)	Runoff (mm)			
		Bare	**Cowpea**	**Maize**	**Cowpea/Maize**
17/5/85	27.0	2.2	0.9	0.8	3.7
23/5/85	33.0	1.8	1.4	1.0	0.9
27/5/85	57.2	3.2	1.6	5.5	11.4
1/6/85	40.5	6.5	2.0	2.0	4.2
12/6/85	74.5	27.2	7.8	17.7	5.2
19/6/85	79.1	9.1	1.7	6.9	5.6
3/7/85	130.5	14.3	8.4	9.8	9.4
7/7/85	53.2	16.0	4.8	9.8	9.4
Total	485.0	80.3	28.4	56.2	61.6
Runoff as % rainfall		16.6	5.9	11.6	12.7

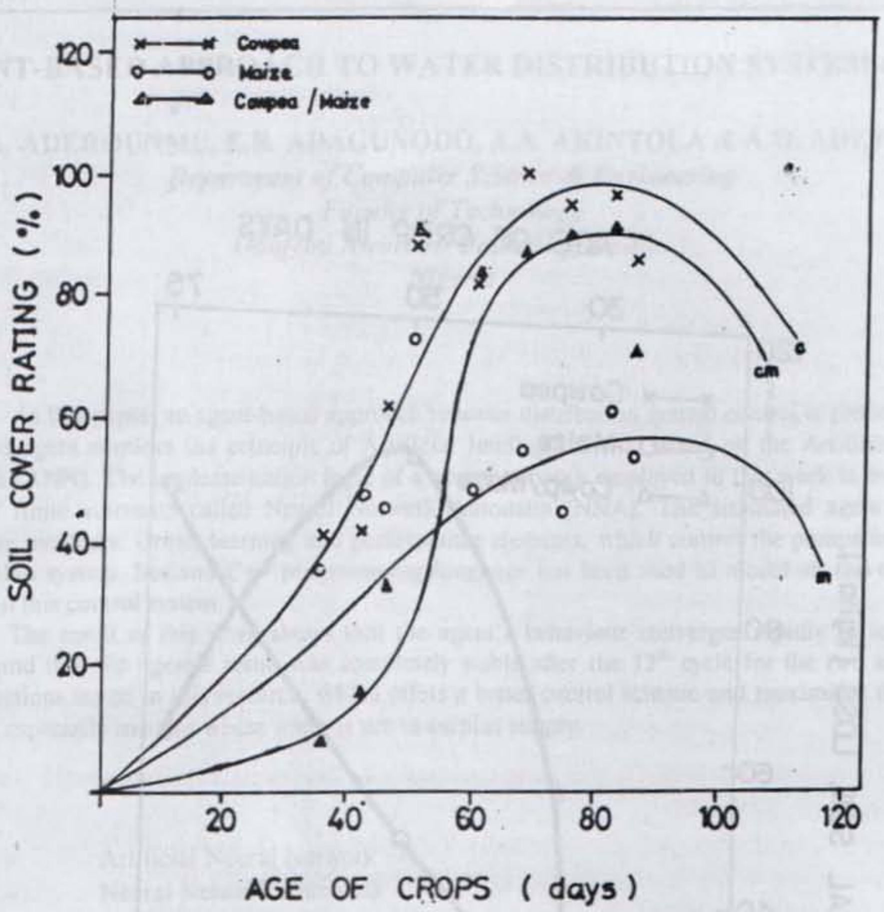

Fig.1. Relationship between cover and age of crop.

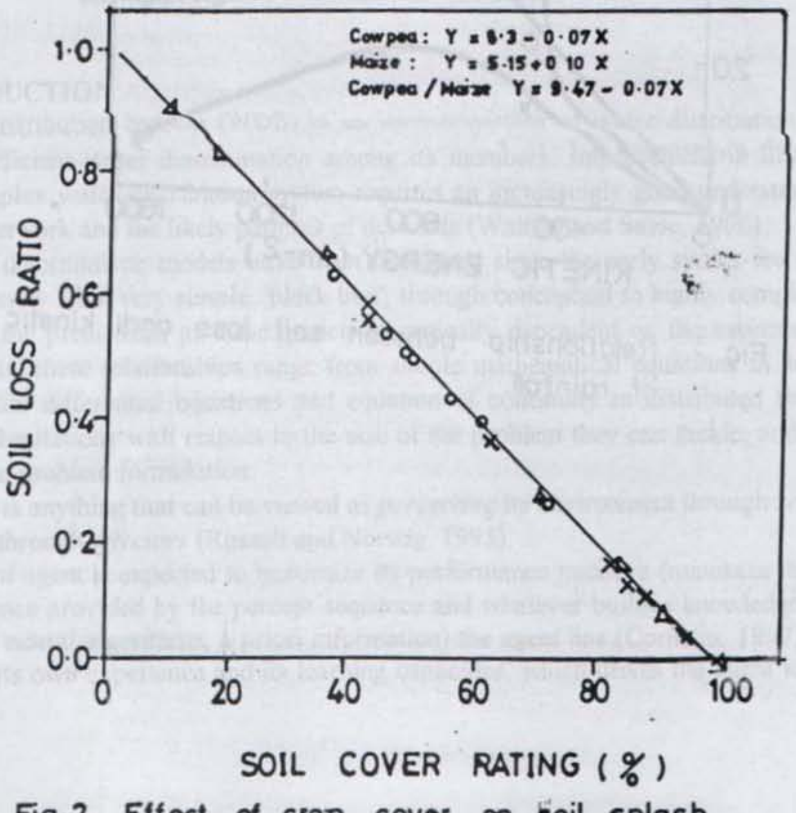

Fig.2. Effect of crop cover on soil splash

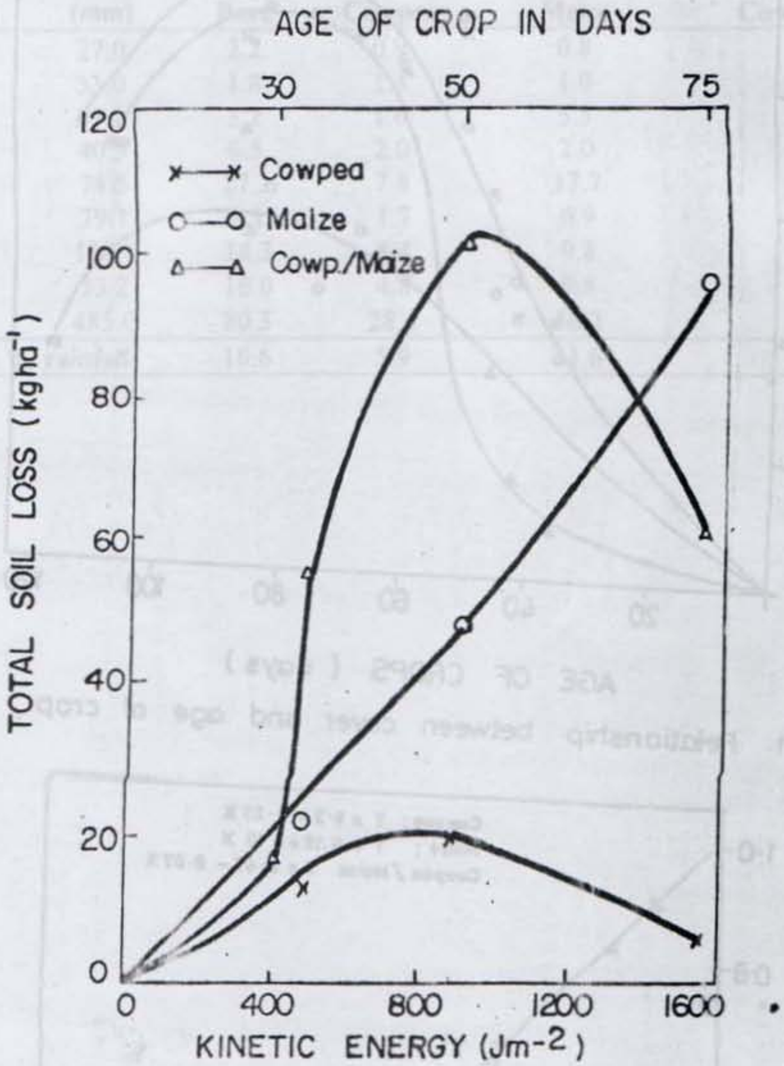

Fig. 3 Relationship between soil loss and kinetic energy of rainfall.

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AN AGENT-BASED APPROACH TO WATER DISTRIBUTION SYSTEM CONTROL

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ABSTRACT

In this paper, an agent-based approach to water distribution system control is proposed. The proposed agent employs the principle of Artificial Intelligence (AI) based on the Artificial Neural Network (ANN). The implementation logic of a neural network employed in this work is based on a class of finite automata called Neural Network Automata (NNA). The simulated agent has the following members: Critic, learning and performance elements, which control the pumps in a water distribution system. Borland C++ programming language has been used to model all the necessary objects in this control system.

The result of this work shows that the agent's behaviour converges rapidly to acceptable values, and that the agent's result was completely stable after the 12th cycle for the two simulated configurations tested in this research, which offers a better control scheme and maximizes the usage of water especially in areas where water is not in surplus supply.

KEYWORDS

ANN	-	Artificial Neural Network
NNA	-	Neural Network Automata
WDS	-	Water Distribution System
AI	-	Artificial Intelligence
IA	-	Intelligent Agent

1. INTRODUCTION

Water Distribution System (WDS) is an interconnection of water distribution elements (sinks and reservoirs) for efficient water dissemination among its members. Improvement in the planning, control and operation of complex water distribution system requires an increasingly good understanding of the resources, the distribution network and the likely patterns of demands (Walters and Savic, 1996).

A wide range of deterministic models have been developed since the early sixties for management of WDS, ranging in complexity from very simple, 'black box', through conceptual to highly complex, distributed models. The accuracy of the predictions of these models is critically dependent on the assumed relationship between inputs and outputs, these relationships range from simple mathematical equations in 'black box' models to a collection of partial differential equations and equation of continuity in distributed models. However, these approaches have limitations with respect to the size of the problem they can tackle, and/or to the assumptions they impose on the problem formulation.

An agent is anything that can be viewed as *perceiving* its environment through *sensors* and *acting* upon that environment through *effectors* (Russell and Norwig, 1995).

A *rational* agent is expected to maximize its performance measure (minimize its cost function) on the basis of the evidence provided by the percept sequence and whatever built-in knowledge (classical algorithms, fuzzy algorithms, neural algorithms, a priori information) the agent has (Corneliu, 1997). Most of its behavior is determined by its own experience and its learning capacities, which drives the agent to have a higher degree of *autonomy*. It should be able to operate successfully in a wide range of environments, given sufficient time to adapt.

The *performance element* is responsible for selecting external actions (control actions) while the *learning element* is responsible for making improvements. It takes some knowledge about the performance element and some feedback from the critic on how the agent is doing and determines how the performance element should be modified to do better in the future. The *problem generator* is responsible for suggesting actions that will lead to new and informative experiences (Corneliu, 1997). Recently, studies of agent technology as applied to deterministic environments (viz. Computer network, weather or climate forecasting etc) indicate that agent technology can provide models capable of good predictions. These flexible tools are capable of modeling complex, non-linear process without having to assume the form of the relationship between input and output variables. The focus of this paper is to investigate the use of this new technology (Intelligent Agent Technology, which employs the concept of Artificial Neural Network) to control the distribution of water in a particular environment.

This research work employs the principle of Artificial Neural Network (ANN) to control the distribution of water in a particular environment.

Section two describes the materials and methods used, while section three discusses the analysis of the result and finally conclusion in the last section.

2. MATERIALS AND METHOD

2.1 Model of the Water Distribution System (WDS)

The particular environment treated in this paper is a Water Distribution System. The water distribution system comprises the following: source, sink, pipe, tank, and pump.

- A *source* supplies water to the system. The source could be a spring, well, or dam. The water from the source is assumed to be always available but cannot be supplied more than a certain fixed rate.
- A *sink* is a user of water. It represents a house, factory, or farm, or a group of such water consumers. A sink absorbs water from the system at a fixed rate.
- A *pipe* carries water over a distance. The water flowing into a pipe equals the water flowing out assuming no leakage.
- A *tank* stores water. It also decouples the input/output flows: The rate at which water flows into the tank can be different from the rate at which it flows out. For example, if the input flow is greater than the output, the content of the tank increases. A tank has a characteristic maximum output rate.
- A *pump* regulates the flow of water. It can be *on*, generating a suction pressure that drives water; or *off*, preventing the flow altogether. The pump uses some sort of servomechanism.

The water distribution system was abstracted as a graph system involving **directed graphs**. This forms the basis for the mathematical model of the environment.

Definition 1: A **graph** G consists of two finite sets (sets having finitely many elements), a set V of points (nodes, or tanks), called **vertices**, and a set E of connecting lines (or pipes), called **edges**, such that each edge connects two vertices, called endpoints of the edge.

Mathematically:

$$G = (V, E) \quad \dots \quad (1)$$

This definition excludes isolated vertices, loops and multiple edges.

We say that a vertex V_i is **inciden** with an edge $e=(V_i, V_j)$; similarly V_j if e connects the two vertices V_i, V_j.

Definition 2: A **directed graph (digraph)** G = (V, E) is a graph in which each edge e = (i, j) has a direction from its "initial point", i to its "terminal point", j.

The digraph was abstracted by the use of *asymmetric* **Adjacency Matrix** $A = [a_{ij}]$
Where

$$a_{ij} = \begin{cases} 1 \text{ if G has a directed edge (i,j)} \\ 0 \text{ else} \end{cases} \quad \textbf{(2)}$$

Figure 2 shows sample water distribution system with six tanks is shown below. Tank 0 is the source Tanks 3,4,5 are the sinks or end users while Tanks 1 and 2 are just intermediary reservoirs. While Figure 2b shows agent's connections to the environment (Water Distribution System).

In the water distribution system each tank in the system could either represent the source (e.g. a dam, river, or well), reservoirs (for temporarily storing water), or sinks which are users of water (e.g. irrigated farmlands, industries, cities etc).

Two tanks in the system are connected together by at least a pipe that conveys water from the upstream to the downstream tank. Each pipe has a pump that drives water in the pipe. These pumps are the devices controlled by the agent to regulate water movement in the system. A sample connection is shown in section V. The following assumptions were made:

- There is an existing water distribution system and all the dimensions and capacities for tanks, pipes and pumps have been preset based on engineering considerations.
- The pumps are controllable automatically by generated signals and the appropriate interface to the computer already exists.
- The sensors connected to the tanks have capacity of determining the contents and state of tanks. It sends signals through appropriate interface. (Suggestions for design of such interfaces are not discussed in this paper).
- The water demand rates of the end users are known. (These values need not be the same).

2.2 Simulated Agent And Its Activities

The simulated agent has all the members shown in figure 2 except the problem generator, which is not necessary for the control system (the water system).

The agent's critic collects information from the environment and passes it back to the agent as reinforcement feedback, which the agent uses as a basis for its training. The learning element consists of a neural network with a learning algorithm.

2.2.1 Learning and Adaptation

The Critic sends a signed and weighted criticism to the agent's neural network. Positive criticisms mean an under supply of water, while negative criticisms mean the supply is above the expected value; this may be a desirable effect in certain systems. The weight of the criticism represents the magnitude of the error.
The learning algorithm uses these criticisms to train each neuron and fine-tune its behavior. Each neuron collects criticisms that concern it based on its input dependencies, i.e. it collects criticisms from tanks that are dependent on the pipe it controls. These criticisms are summed and scaled based on the neuron's weight; the weight is also adjusted to favor reduction in the next criticism. The target is to reduce the criticisms to zero, at this point, system resources are optimally utilized.

2.2.1.1 Initialization

2.2.1.1.1 Creation of Dependency Lists

The agent collects the environment's adjacency matrix, analyses it and uses it to form virtual internal connections similar to the physical system's physical configuration, it then starts the analysis of this internal prototype.

It creates a dependency list of paths to each tank in the system, i.e. a list of all paths from the source tank to each final (target) tank; it then determines which path is the shortest from source to the target and gives it the highest priority, the other paths receiving priorities based on their lengths with inverse proportionality, i.e. longest path has the least priority in supplying the demands of a tank.

Each pipe on a path is then prioritized accordingly. The mathematical bases of this are discussed offline. The path weightings are done to favor flow towards pure sinks.

2.2.1.1.2 Creation of Neural Network

The agent developed for the WDS has internal automations to create an optimal, preemptively weighted neural network for the system. It uses the results from the internal prototype to form a neural network, with a neuron controlling pump on each pipe in the system. Each pipe has a tank dependency list, i.e. a list of tanks through which water flows to each the pipe.

The weight on the output axon of each neuron is the same as the set weight for the pipe it controls. The neural network has one layer. The agent collects the physical address of the pipes and stores them on corresponding neurons so that the neuron may be able to control the modeled pipe.

2.2.1.1.3 Operation of the Agent

The operation of the agent is described in the flowchart of figure 3. The agent starts by sending control signals to the WDS, it then receives feedback from the WDS which now forms the bases on which the agent trains itself (its neural network).

These actions continue for as long as the system is to be controlled. The agent starts with a probable imperfect guess of the right control signals and fine-tunes these signals to convergence to stable values during the training period.

3. SIMULATION, RESULTS AND ANALYSIS

Simulations were carried out with two different WDS. The first has six tanks with three pure sinks, while the second has 11 tanks with six pure sinks.

In both cases the flow demand for each pure sink was set arbitrarily to 100 volumes per cycle (a cycle is a unit of time, which could be a week, a day, an hour, a minute depending on the inertia of the system; generally the smaller the duration of a cycle, the better the performance of the agent). Also the total amount of water available per cycle was set to the total per cycle flow demand of all the sinks to justify the convergence of the agent's criticism to zero.

The water utilization in percentage and tanks dissatisfaction (criticism) were used as measures of performance for this agent.

Assuming:

DDm ≡ Water demand of Tank m in a cycle

SSm ≡ Water supply to Tank m in the cycle

TSS ≡ Total available water in the cycle

UtilSum ≡ Sum of correctly Utilized volume of water in the system in the cycle

n ≡ number of sinks in the system

UtilSum =0

UtilSum = UtilSum + SSm (m=1,2...n) {also take SSm as DDm if SSm >DDm}

Utilization = UtilSum/TSS
Criticism = DDm - SSm

The water utilization is plotted as a percentage of the total available system resources during a flow session. The variation in tank criticisms was also plotted; this is shown in figure 4.

From the graph it could be seen that the agent's behavior converges rapidly to values that indicate minimal criticisms, and that the agent's result was completely stable after the 12^{th} cycle for the two configurations. The performance slackness in the second configuration shows the slight imperfection in the flow mechanism of the simulated water system; it is not completely parallel, it uses some sort of asynchronous ripple-like flow mechanism to approximate the completely parallel flow that is obtained in reality.

4. CONCLUSION

The agent-based approach has been proposed for the water distribution system. The simulated environments assumed stability easily under the agent's control.

The result of this approach eliminates the limitations highlighted in the introduction section above. As opposed to the existing schemes, the results of our scheme shows that it provides functionality for handling non-linearity, it is robust and fault tolerant.

It could be shown that many other control environments could be modeled mathematically as directed graphs, hence allowing for the agent's scalability to such environments. Special attention was given to the learning element based on the principle of the Artificial Neural Network, which enhances autonomy of the agent in the WDS.

The learning algorithm used in this work for environments with relatively stable demands achieved stable and relatively accurate control.

In future, learning algorithms like the Stochastic Estimator Learning Algorithm (SELA), would be employed to make provision for environments with non-stationary stochastic demands. Also further experiments would be made with different configurations, learning algorithms, and environments to further explore the agent's efficiency and scalability.

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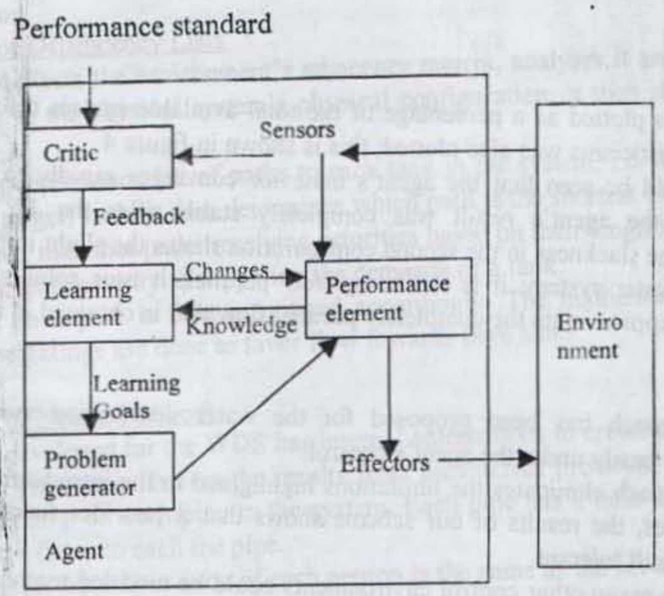

Figure 1: Autonomous agents

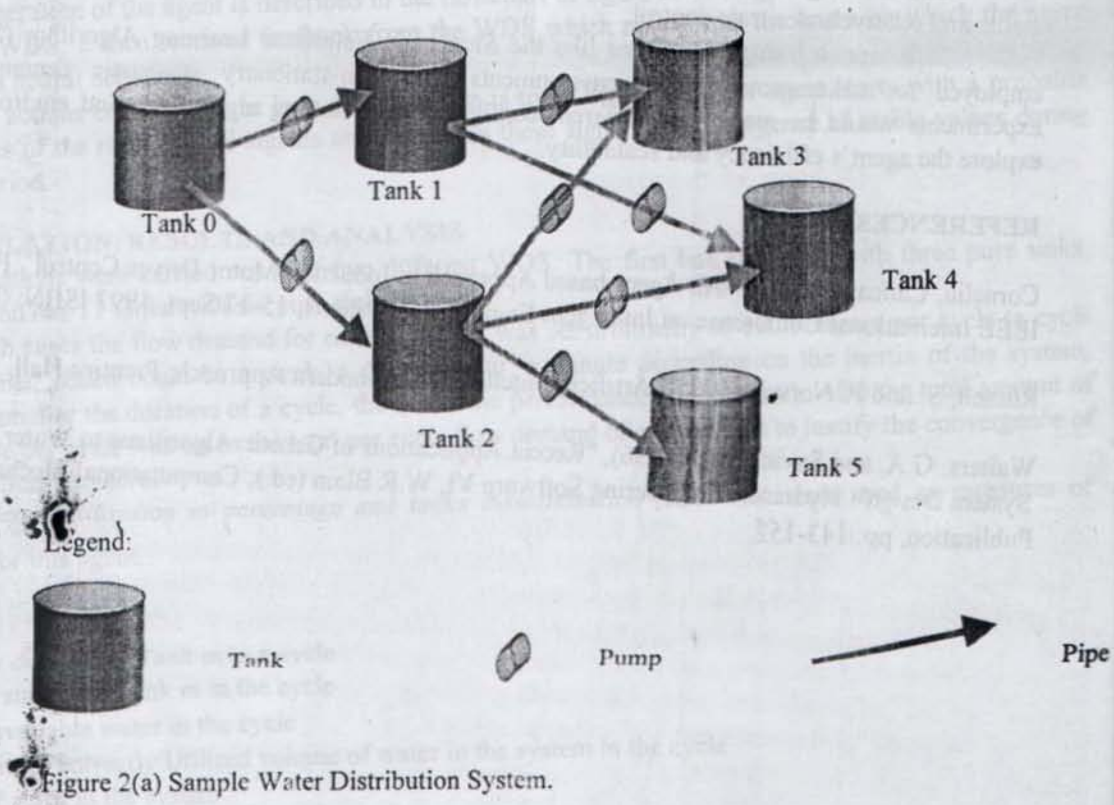

Figure 2(a) Sample Water Distribution System.

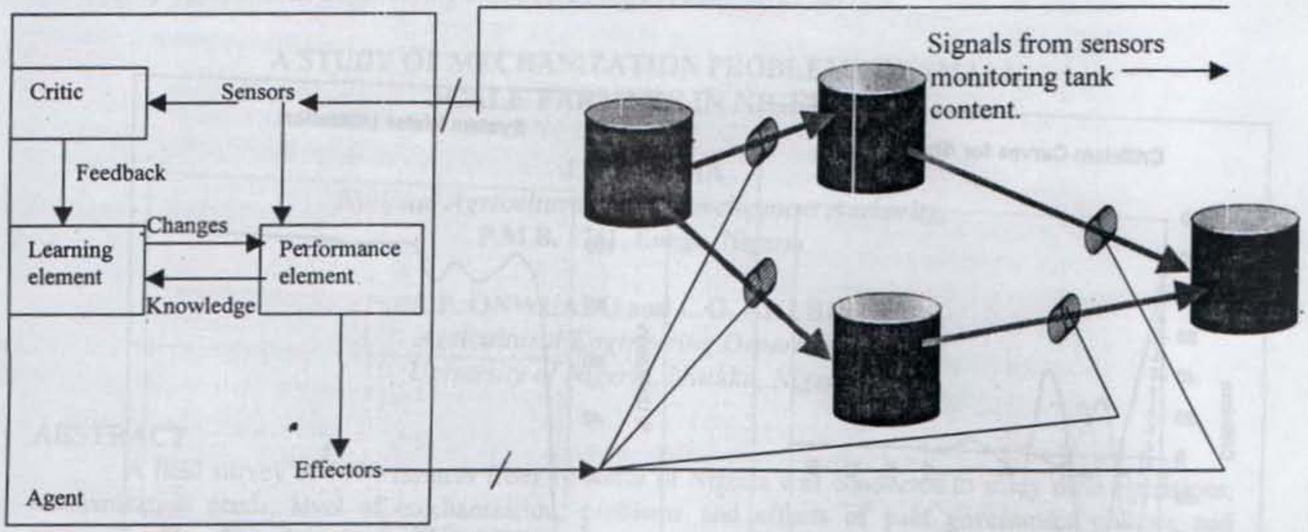

Figure 2(b). Sample water distribution system showing agent's connections.

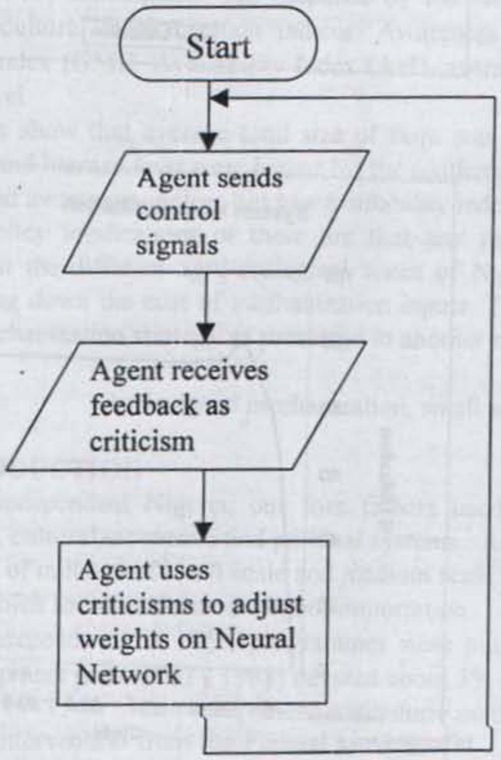

Figure 3. Agent's control flowchart

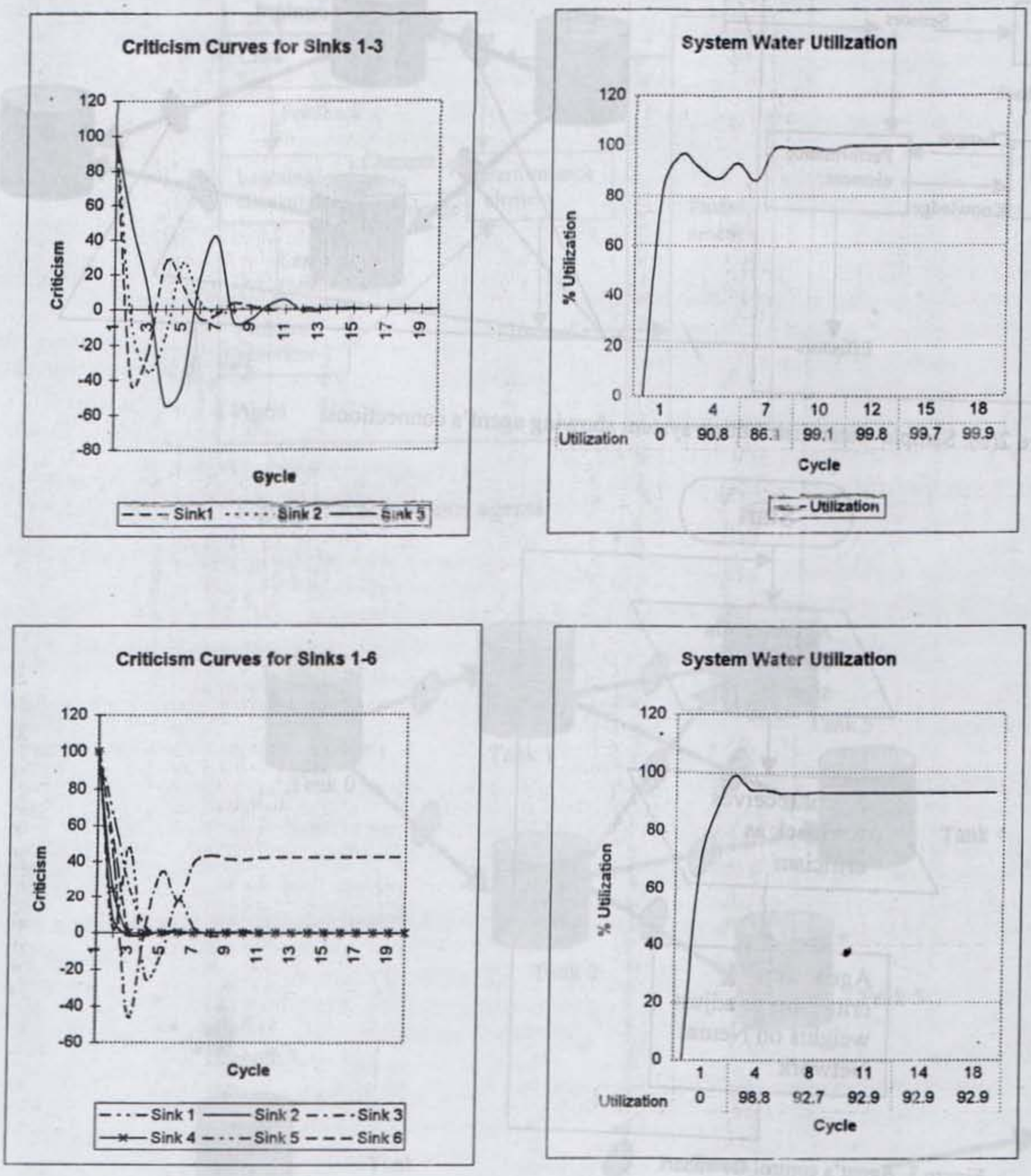

Figure 4: Variation in Tank Criticism and Water Utilization

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A STUDY OF MECHANIZATION PROBLEMS OF SMALL SCALE FARMERS IN NIGERIA

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ABSTRACT

A field survey of 1690 farmers from 10 states of Nigeria was conducted to study their operations, mechanization needs, level of mechanization, problems and effects of past government policies and programmes on their operations. The approach used was based on blending the investigative approach of Anazodo (1982) with Rapid Rural Appraisal (RRA) and Rapid Appraisal of Agricultural Knowledge Systems (RAAKS) techniques. The response by the farmers were aggregated and analyzed using the following agricultural mechanization indices: Awareness Index (AwI), Willingness Index (WI), Good Management Index (GMI), Availability Index (AvI), average total size of farm, degree of fragmentation, and literacy level.

Results show that average total size of farm was higher for the northern states while degree of fragmentation and literacy level were higher for the southern states. The farmers had high willingness, good management and awareness indices but low availability index.

The policy implications of these are that any mechanization policy to be adopted should be modified to suit the different agro-ecological zones of Nigeria and government should intensify efforts towards bringing down the cost of mechanization inputs. The results were used to develop an alternative agricultural mechanization strategy as presented in another report (Adama et al, 1998).

KEY WORDS: Agricultural mechanization, small scale farming, degree of fragmentation

1. INTRODUCTION

In pre-independent Nigeria, our fore fathers used a system of agricultural production which sustained social, cultural, economic and political systems. Adequate food production was achieved through the mobilization of millions of small scale and medium scale farmers. The results were abundant food and raw materials which satisfied demand without importation.

After independence in 1960, programmes were put in place to maintain that system. The first National Development plan (1962 - 1968) devoted about 3% of the total capital outlay to agriculture. By 1963, the constitution placed agriculture on the responsibility of the Regional Governments with minimum intervention from the Federal Government. The regional governments started with farm settlement schemes in eastern and western regions and training institutes in the north. Shortly, it was not difficult to associate specific crops and produce with regions; palm produce in the east, cocoa in the west, rubber in the mid west and groundnut in the north. Then, more than 75% of the estimated population of 55 million was engaged in farming and over 80% of all foreign exchange earning came from agriculture (Oguleye, 1992). But oil has since changed that picture. In 1970, over N176 million was earned from oil, rising to N1.38 billion in 1973. Between 1979 and 1983, production reached an all time high of 2.3 billion barrels a day. Within that period, the country earned N43.6 billion from the product alone rising to N12.5 billion in 1993 (Chukwuemeka, 1993).

The result of this was that while the share of oil and mining in the Gross Domestic Product (GDP) and the nation's export increased geometrically, the share of agriculture decreased alarmingly. For instance, the share of agriculture in Nigeria's exports decreased from 80% in 1960 to a disappointing 3.7% in 1980. At the same time, the share of oil and mining increased from 15% in 1970 to 92% in 1980 (Odigboh and Onwualu, 1994). This was because the government paid less serious attention to agriculture and started to import the basic food stuff and raw materials. For instance, food import in Nigeria in 1979 amounted to N18.8 million, N1.16 billion in 1980, and N1.86 billion in 1981, (Chukwuemeka, 1993). The share of food imports in total imports into Nigeria rose from 8.6% in 1976 to 21% in 1984 (Odigboh and Onwualu, 1994). As agriculture was neglected, the large percentage of Nigerians who were engaged in farming deserted that sector too, leaving the aged class in the farm. The young ones trooped out to the urban centres in search of white collar jobs. But the oil sector could not absorb the number that was trooping out. This resulted into high rate of unemployment.

To compound the problem, the price of oil crashed in the world market. In 1980, oil sold for $40 a barrel, but in 1993, it sold for $14. There were budget deficits. And the government realised the dangers of operating a mono product economy. Like the husband who after being abandoned by a fair-weathered second wife turned to the first wife for succour, government attention was again re-focussed on agriculture.

The continued neglect of agriculture has also limited the farmers to the use of hand tools for all operations in the field, so that there is virtually absence of mechanization on Nigerian small scale farms (Essang, 1973, Ijere, 1976; Oyolu, 1976; Oyaide, 1979; Anazodo, 1980; Anazodo, 1982; Subair 1986; Oyatoye, 1988; Odigboh, 1988; Odigboh and Onwualu, 1994, Adedoyin et al, 1996). However, it is generally agreed that agricultural development in Nigeria hinges on the introduction and use of appropriate and sustainable mechanization technology into the existing traditional family farming system. This is probably why the government has embarked on a number of programmes including the National Agricultural Land Development Authority (Lombin and Fagbami, 1994) and the Family Economic Advancement Programme, FEAP (Aliyu, 1998). The failure of similar projects in the past has been blamed on the top-down approach used by agricultural administrators. Current development strategies emphasize sustainability, people-oriented and community based approaches (Eboh et al., 1995). In such strategies, ideas are generated from the people and development is pursued by the people, with the government providing necessary support services.

Such an approach to agricultural mechanization was recently proposed (Adama, 1997; Adama et al, 1998) A necessary step towards the development and implementation of the approach is a detailed study of the farmer and his mechanization needs and problems. Such a study was conducted by Anazodo (1982a; 1982b) using what he called the investigative survey approach. In that study, the problems associated with mechanization were aggregated into quantifiable indices. It is over a decade since that work was published. Yet the problems of the small scale farmer may even be worse today. There is therefore the need to take another look at the problem with expanded indices. One limitation of the study by Anazodo (1982) is that the survey was on selected communities in eastern Nigeria, giving rise to the need for a more national survey. A comparison of the indices obtained in 1982 with current indices would reveal the progress or other wise made towards agricultural mechanization since over a decade of agricultural development programmes in Nigeria. Such a comparison may suggest shift in policy for the government.

The objectives of this study therefore, were to conduct a field survey of family farms in Nigeria in order to determine Availability Index, Willingness Index, Awareness Index and other factors limiting or

programmes in Nigeria. Such a comp

The objectives of this study therefore, were to conduct a field survey of family farms in Nigeria in order to determine Availability Index, Willingness Index, Awareness Index and other factors limiting or
encouraging the mechanization of the farms, using a modified form of the investigative survey approach of Anazodo (1982a; 1982b).

2. METHODOLOGY

2.1 Approach of study

A comprehensive study on the mechanization of family farms in Nigeria was undertaken by Adama (1997). The study was in three phases. Phase one involved a systematic review of literature on mechanization of family or small holder farms in particular and agricultural development programmes in general. The second phase involved a study of small holder farms using a modified version of the Investigative Survey Approach of Anazodo (1982a; 1982b). The third phase was the development of a strategy and programme for the mechanization of family farms in Nigeria. This paper presents only the second phase of that study, in order to keep the size within limits.

The approach used is based on blending the Investigative Survey Approach of Anazodo (1982) with Rapid Rural Appraisal, RRA technique (Grandstaff and Grandstaff, 1987) and Rapid Appraisal of Agricultural Knowledge Systems (RAAKS) technique (Salomon, 1997).

A combination of these approaches was necessary to ensure that the data obtained is a true [illegible] With the

A combination of these approaches was necessary to ensure that the data obtained is a true
representation of the facts. The Investigative Survey Approach uses mostly questionnaires. With the nature of farmers to be interviewed, distorted information can be obtained. The RRA emphasises the quick acquisition of information in an informal interview using check lists. This approach was used to get the farmers to "loosen" up and become friendly. The RAAKS approach emphasises learning from the farmers about their own experience. This necessitated the use of informal workshops before the survey, during the survey and after the survey.

2.2 Research Questions

The questionnaire used in the study was based on a modification of that developed by Anazodo (1982a). Research questions were grouped into six (A,B,C,D,E,F). The first section (A) was on general background information of the farmer. There were ten questions seeking information on the state of origin, local government area, community, village, marital status, sex, age, occupation, main crops and animals and the educational attainment of the farmer.

In the second section (B), 15 questions were asked to determine how informed the farmer was with respect to the existence of relevant inputs to modernized agriculture with emphasis on agricultural mechanization related ones. The questions were on awareness of the existence of land use decree, Nigerian Agricultural and Cooperative Bank (NACB), National Agricultural Land Development Authority (NALDA), National Centre for Agricultural Mechanization (NCAM), Agricultural Development Projects (ADP), Tractor and Equipment Hiring Companies, operation of tractors, fertilizer, agro-chemicals, and machines for agricultural work.

The third set of questions (C) was on the use of improved techniques for production by the farmers. Seven questions were asked on whether they practiced continuous cultivation, monocropping, crop rotation, fertilizer, farm yard manure and record keeping.

The fourth set of questions (D), was on the availability of mechanization and related inputs to the farmer. There were twelve questions that had to do with availability of land, basic infrastructure such as roads, ownership of machinery such as tractors, accessibility to loans, and availability of fertilizer, labour and improved seeds.

The fifth set of questions (E) was on the willingness of farmers to be involved in agricultural mechanization related operations. There were 22 questions having to do with the willingness to merge with other farmers, to give out land to government sponsored projects, use agricultural machinery, obtain loan from NACB, participate in other programmes etc.

The sixth set of questions (F) was on other important attributes including size of farm, number of farm units owned, cost of operations, etc. The responses are mostly Yes or No for easy filling of the questionnnaire. Other information obtained include problems handling the use of machines in agriculture. Detail of questions are shown in tables 1-4.

2.3 Administration of Questionnaire

A total of 1960 farmers were interviewed nationwide either in their homes or on their farms. The farmers were selected at random from the relevant states. The geographical distribution of the farmers interviewed were Enugu State - 250; Cross River State - 100; Ondo State - 250, Oyo State - 150; Kogi State - 200; Niger State 180; Kaduna State - 100, Sokoto State - 150; Bauchi State - 170 and Bornu State - 140. Thus, the survey covered ten states which are selected such that all the agro-ecology zone of the country were covered and shown in Fig. 1. The numbers covered in each state varied because of the logistic problems but the target was to interview at least 100 farmers in each selected state.

To obtain the required information, the extension staff of the various state ADPs and NALDA was used. All the enumerators were trained on how to fill the questionnaires through a training workshop conducted before the survey and after. Since some farmers could not fill the questionnaires, this was done for all farmers by the enumerators. Where necessary, the interviews were conducted in the local language. Emphasis was placed on learning from the farmer before asking the questions This was done in informal workshops, as demanded by RAAKS approach.

2.4 Data Analysis

The information in the completed questionnaires were collated and analysed. For sections B, C, D and E of the questionnaire, each Yes answer to a question was counted as a positive score and considered favourable if the affirmative positive score and considered favourable if the affirmative answer was adjudged to favour mechanization. The percent positive score for each question was obtained by dividing the number of farmers who responded positively to the question by the total number of respondents. This was based on the approach developed by Anazodo (1982a). The mean percent positive score for the 10 questions in section B of the questionnaire, which had to do with Awareness, was calculated and referred to as Awareness Index (AwI). The corresponding index for section C of the questionnaire was Good Management Index (GMI), that for section D was Availability Index (AvI) and that from section E was Willingness Index (WI).

The effect of location and literacy level of the farmers on these indices were determined. Other parameters calculated were standard deviation and coefficient of variation for the farm sizes, average total size of farm, number of farm units, degree of fragmentation and degree of literacy. The degree of fragmentation (DF) was obtained using the formular:

$$DF = \left(\frac{n-1}{n}\right)100\%$$

where n is the number of farm units owned by the farmer.

3. RESULTS AND DISCUSSION

3.1 Awareness Index (AwI)

The Awareness Index (AwI) indicates the degree of awareness of farmers on the possibilities and institutional facilities that exist for mechanizing their farms. The results obtained are shown in Table 1.

Many farmers are aware of the existence of improved biochemical, socio-economic and mechanization inputs in agriculture as shown by the over 50% positive score on most of the questions in

Table 1. The only questions that attracted less than 50% positive scores were those on the land Used Decree, NCAM and price of a tractor. The awareness of the land use Decree is low because the government has not really been promoting information dissemination when the land is needed for a public facility. That of NCAM is low because it is a relatively young organization without subcentres. The score on awareness of cost of tractor is low because most farmers only know that the cost is too high and since they don't ever attempt buying, they have never really priced them. The general relative high percent positive score for other questions is in line with sustained efforts at educating farmers through a number of projects and programmes including ADPs, NCAM, NALDA etc. Usually public campaign through the mass media and local governments accompany these programmes.

A comparison of the results with that of Anazodo (1982a) shows that the values of the scores and the index in the present study are higher. This can be attributed to modernization resulting in farmers having more access to information. Between 1981 and 1993 when the present study started, many agencies have been created, new states and local governments have been created, and the Structural Adjustment programme (SAP) has forced more people back to farming, thus generating more awareness. Thus, it can be concluded that considerable progress has been made in educating farmers between 1982 and 1997. However, it should be noted that for agricultural mechanization to be achieved the percent positive score should approach 100% so that farmers can make informed choices.

3.2 Good Management Index (GMI)

Good Management Index (GMI) expresses the suitability of the farmers' present management and cultural practices to the effective introduction of mechanized methods. Results of the good management index obtained for all the farmers are shown in

Table 2. The GMI were generally relatively low. Only two questions that had to do with application of farmyard manure and practice of crop rotation gave very high percentage scores of up to 80%. The rest were just 50% or less. Thus it can be concluded that although many campaigns and programmes have been launched and executed, the average Nigerian farmer's use of improved technique for agricultural production is still low.

This may be attributed to the non availability and high cost of these inputs as shown by availability index (discussed later).

In comparison with the results obtained by Anazodo (1982), Table 2 shows that the GMI obtained in this study is higher. While the GMI was 38% in 1982, the current value is 51%. This shows a moderate increase in the modernization of small scale farms in Nigeria. As noted earlier, for considerable progress to be made, the GMI should approach 100%.

3.3 Availability Index (AvI)

The Availability Index (AvI) is a quantitative measure of the actual availability of the technological innovations in agricultural mechanization to the farmer. It is also an indication of the agricultural mechanization status of the farmer. In general, AvI was found to be low among the farmers as shown in Tables 3. The Table shows that but for land resources, labour and extension service, other facilities required for the mechanization of family farms in Nigeria have very low percent positive score. The results therefore show that there is virtually absence of mechanization inputs for the rural farmer (family farmers). This is an indication that the status of agricultural mechanization at the family farm level is still very low across the country.

The abnormally low percent scores of the questions on availability of agricultural machines should be noted. This should also be put together with the equally low score on the questions dealing with availability of capital and loan. Thus, the non availability of the mechanical input can be directly linked to non availability of capital.

3.4 Willingness Index (WI)

The Willingness Index (WI) gives a quantitative evaluation of how willing the farmers are to accept and adopt better management techniques, technological innovations and credit facilities. The results are shown in Table 4. The results show very high percent positive scores on the willingness of the farmers to accept and adopt programmes developed for mechanizing their farms. For instance, the willingness of the farmers to merge their scattered and small land units with their neighbour for introduction of tractorized equipments has a positive score of 85% while that on the formation of association with the neighbours has a score of 87%. Other scores within the components of our approach range from as low as 65% and to as high as 90%. However, the willingness of the farmers to give out their land to the government, a company or an individual for commercial agriculture has very low scores (5 - 28%). This simply shows that the farmers are unwilling to give out their land for a project in which they are not fully involved. And this is probably why the Land use Decree has not been able to solve the problem of land tenureship in Nigerian agricultural mechanization. The very high positive scores recorded in other questions favouring our approach have removed the conception that Nigerian family farmers are conservative and so are unwilling to adopt any programme meant for the mechanization of their farms.

Table 4 also shows that the percent positive scores were higher in the study reported by Anazodo (1982a). This could be attributed to the more careful attitude of farmers occasioned by the general economic situation caused by the Structural Adjustment Programme (SAP).

3.5 Effect of Location on the Indices and Other Attributes of Farmers

Results presented in Table 5 show that some degrees of variation exist in such parameters as farm size, number of farm units and degree of fragmentation. For instance, in Enugu State, the average size of farm owned by a farmer is 0.4 ha while in Borno State the size is as large as 4 ha. In Enugu State the degree of fragmentation is the highest (80%) followed by Cross River and Kogi States with degrees of fragmentation being 75% each. Borno State has the lowest in the degree of fragmentation of 50% along with Niger and Kaduna States. This means that farm sizes are smaller in Enugu areas with higher number of units and larger in Northern zones with smaller number of units.

This is consistent with the higher population density in the Southern States. In addition, the land tenure system is more in the South. Therefore, any agricultural development programme to be embarked upon by the Federal Government should take into consideration these variations.

The coefficients of variation calculated from field data showed that significant variations exist for farm sizes not only within the Villages and Local Governments as shown by Anazodo (1982b) but also among the States in different ecological zones of this country as shown in the table. The variations for other parameters are significantly low.

3.6 Effect of Literacy Level on the Mechanization Indices and other Attributes of Farmers

For all the states studied, literacy level significantly affected the indices obtained. Table 6 shows that literate farmers have higher Awareness Index, Good Management Index and Willingness Index.

These could be attributed to the fact that the literate farmers are usually, people involved in other businesses such as teaching, and trading. They are usually slightly more wealthy and influential than the illiterate ones. Therefore, they are better informed and are equipped to pursue issues even without extension agents. This study has therefore once more brought out the need for some level of education for farmers since this will enable them achieve more in their endeavours.

3. CONCLUSION

This study has quantitatively evaluated the problems facing the mechanization of agriculture in Nigeria in general and that of family farms in particular. It was found that in spite of high Willingness

Index, the Availablity and Good Management Indices as well as mechanization Status remain low. In other words, although the farmers are willing to adopt improved systems, the availability of such systems is low. The reasons for this were identified as high cost of biochemical and mechanization inputs, small, fragmented and scattered land holdings and dwindling capacity of government to provide facilities needed for mechanizing the farms. The mechanization indices were affected by location and literacy level of farmers. This indicates that any strategy to be developed for mechazation should vary between the various agro- ecological zones of the country. The results of the study were used to develop a new approach to mechanization of small holder farms in Nigeria which is the subject of another paper (Adama et al, 1998).

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Table 1. Awareness Index (AwI)

S/N	Question	Percent positive score	
		Anazodo . 1982a*	Present Study + 1997
1	Are you aware of the existence of the Land Use Decree?	-	40
2	Are you aware of the existence of the Nigerian Agricultural and Cooperative Bank (NACB)?	51	65
3	Do you know how to obtain loan from NACB?	46	50
4	Are you aware of the existence of Agricultural Credit Guarantee Scheme?	-	55
5	Are you aware of the availability of improved varieties of seeds and seedlings?	-	60
6	Have you heard of National Agricultural Land Development Authority, NALDA?	-	58
7	Are you aware of the existence of National Centre for Agricultural Mechanization, NCAM?	-	45
8	Are you aware of the existence of the Agricultural Development Projects, ADP?	-	60
9	Are you aware of the existence of tractor and equipment hiring units?	52	70
10	Have you ever witnessed a demonstration of tractorized agricultural machinery?	73	85
11	Have you ever seen any tractorized agricultural machinery under actual field operation?	77	82
12	Do you know how much a tractor costs?	11	25
13	Do you know the official price of a bag of fertilizer?	-	56
14	Are you aware of the existence of weed control chemicals and sprayer?	-	70
15	Are you aware of the existence of different machines for farm work?	-	80
	Average percent Score or Awareness Index	52	60

+Number of respondents = 1690.

*Data in this column reported by Anazodo (1982a) for some communities in 4 eastern states.

-Question not asked by Anazodo (1982a).

Table 2. Good Management Index (GMI)

Question		Anazodo 1982a*	Present Study 1997
1	Do you practice continuous cultivation	22	36
2	Do you grow only one crop in your largest land unit?	4	40
3	Do you practice crop rotation?	73	80
4	Do you plant your main crop on the flat?	27	42
5	Do you apply fertilizer?	47	50
6	Do you apply farm yard manure?	71	80
7	Do you keep any records of your farm business?	25	30
	Good Management Index	38	51

*Based on a study reported by Anazode (1982a) for 2 states.

Table 3. Availability Index (AVI)

S/No	Question	Percent Positive Score
1	Do you have abundant land resources for mechanized agriculture?	85
2	Is the road to any of your farm unit motorable?	4
3	Do you have electricity in any of your farm unit?	2
4	Is irrigation water available in any of your farm?	29
5	Do you have tractor for farm operations?	3
6	Is tractor hiring service available in your area?	60
7	Is hired labour available in your area?	90
8	Is fertilizer readily available in your locality?	25
9	Do you readily obtain loan from NACB?	6
10	Is extension service available in your area?	55
11	Do you have the capital to buy tractor and other farm implements?	1
12	Do you have other prime movers such as petrol, diesel engines and electric motors?	20
	Average percent score or availability Index	30.8

This index was not used by Anazodo (1982a).

Table 4. Willingness Index (WI).

Question		Percent positive Score	
		Anazodo 1982	Present Study 1997
1	Will you be willing to merge your scattered land units with your neigbour for economic introduction of tractorized equipment?	-	85
2	Will you be willing to from an association cooperative society) together?	97	87
3	Will you be willing to own farm jointly with your neighbours? That is joint farm enterprise)	-	45
4	Are you willing to give your land to (a) Federal Government? (b) State Government? (c) Local Government? (d) A Company? (e) An Individual? For a mechanized agricutural project	- - - - - -	28 28 24 15 5
5	Are you willing to adopt suitable erosion control measures?	-	80
6	Are you willing to crop on irrigated farm land?	-	75
7	Will you be willing to buy a tractor if you are given adequate loan facility?	100	90
8	Will you be willing to own and use tractor jointly with your neighbours with whom you pooled your farm units?	99	85
9	Are you willing to benefit from the services of tractor hiring company?	100	95
10	Will you want to obtain a loan from the NACB to buy required inputs?	63	72
11	Will you agree to use the tractor to work for other farmers?	-	70
12	Are you willing to buy improved seeds and seedlings?	95	84
13	Are you willing to use tractorized equipment for one or more of your crop production operation?	100	90
14	Are you willing to adopt monocropping in your largest land unit?	84	90
15	Will you wish to apply fertilizer?	95	84
16	will you like to have extension officers visit your farms regularly ?	-	90
17	if this loan is granted to you will you use it for agric purposes only?	-	70
18	will you be willing to have account with any commercial bank?	-	88
19	Are you willing to benefit from the activities of NALDA if you have not?	-	87
20	Will you agree to allow farm roads pass through your own portion of the pooled land?	-	65
21	Will you partispate in the maintenance of roads, drainage system, etc?	-	85
22	Are you willing to contribute money, materials and labour for the provision of such amenities as roads, draomage system, well, electricity, machine house, storage house, etc. In the centre?.	-	85
	Average Positive Score or Willingness Index	69	92

Table 5: Effect of Location on Mechanization Indices and other Attributes

State	NOR	AwI %	GMI %	AvI %	WI %	ATS (ha)	ANF	DF %	DL %
Enugu	250	68	50	30	65	0.4	5	80	48
C/River	100	65	48	29	80	1.8	4	75	51
Ondo	250	10	60	30	38	2.0	3	67	49
Oyo	150	64	44	31	68	1.7	3	67	52
Kogi	200	63	49	33	64	1.0	4	75	40
Niger	180	54	61	29	67	2.4	2	50	38
Kaduna	100	56	40	34	68	2.5	2	50	45
Sokoto	150	55	54	30	73	2.3	3	67	40
Bauchi	170	50	54	28	70	3.0	3	67	35
Borno	140	58	51	32	66	4.0	2	50	36
Mean	NA	60	51	31	69	1	3	65	43
Mean Dev.	NA	6.27	6.19	1.8	5.16	0.95	0.94	10.56	6.03
Std Dev	NA	6.62	6.52	1.89	6.44	1.00	0.99	11.13	6.36
COV	NA	11	12	6	7	47	36	17	15

NOR = Number of respondents
AwI = Awareness Index
AvI = Availability Index
WI = Willingness Index
ATS = Average total size of farm
ANF = Average Number of Farms
DF = Degree of Fragmentation
DL = Degree of Literacy

COV = Coefficient of Variation
Std.Dev= Standard Deviation
NA = Not applicable

Table 6. Effect Literacy Level on Agricultural Mechanization Indices

State	Index	Literate*	Illiterate
Enugu	Awareness Index	85	51
	Good Management Index	80	20
	Availability "	30	30
	Willingness "	98	32
Cross River	Awareness Index	40	90
	Good Management Index	85	11
	Availability "	29	29
	Willingness "	98	62
Ondo	Awareness Index	95	45
	Good Management Index	79	61
	Availability "	30	30
	Willingness "	98	58
Oyo	Awareness Index	94	34
	Good Management Index	70	18
	Availability "	31	31
	Willingness "	91	45
Kogi	Awareness Index	89	37
	Good Management Index	90	8
	Availability "	33	33
	Willingness "	86	42
Niger	Awareness Index	83	25
	Good Management Index	89	33
	Availability "	29	29
	Willingness "	90	44
Kaduna	Awareness Index	70	42
	Good Management Index	95	40
	Availability "	34	34
	Willingness "	69	11
Sokoto	Awareness Index	73	37
	Good Management Index	80	56
	Availability "	30	30
	Willingness "	75	40
Bauchi	Awareness Index	60	40
	Good Management Index	85	23
	Availability "	28	28
	Willingness "	95	45
Bornu	Awareness Index	78	38
	Good Management Index	90	12
	Availability "	32	32
	Willingness "	88	44

*Literate farmer is defined as that who got education up to primary school level and usually can speak English Language.

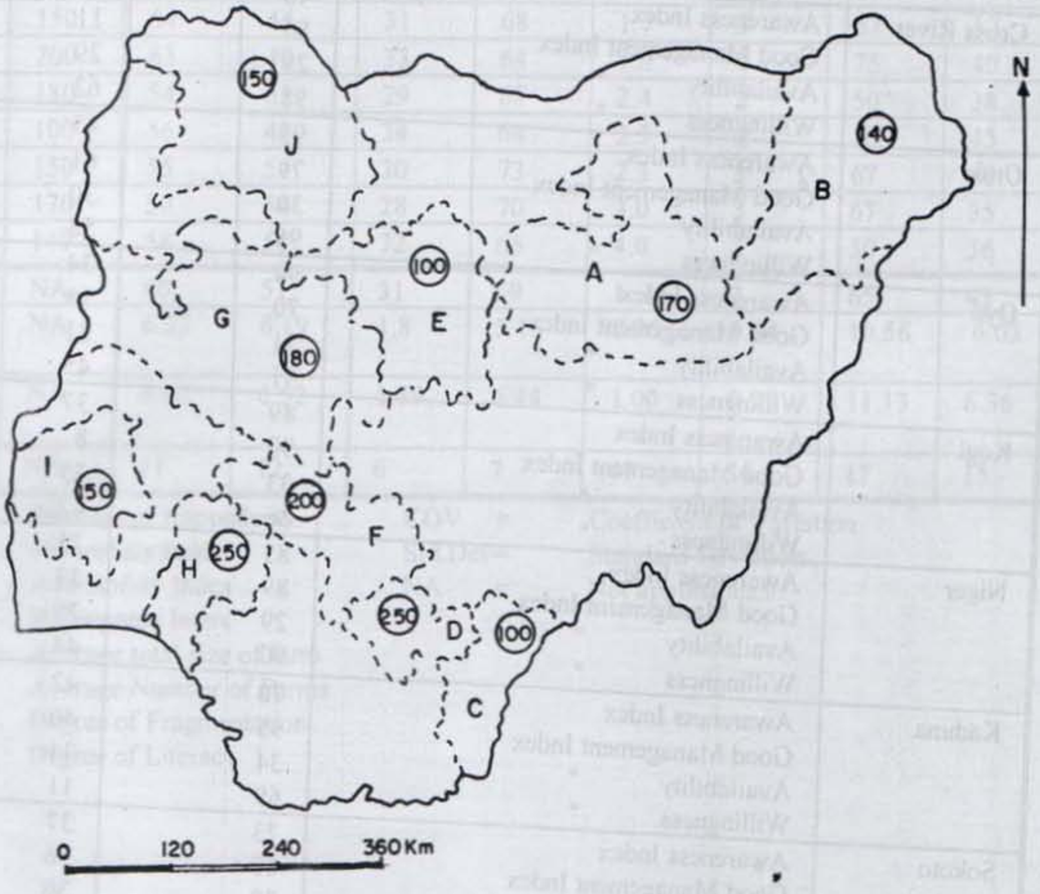

Fig. 1. Map of Nigeria (as of 1995) showing the states and number of farmers surveyed (circled) in the various states, A, Bauchi; B, Bornu; C, Cross River; D, Enugu; E, Kaduna; F, Kogi; G, Niger; H, Ondo; I, Oyo and J, Sokoto. ~ National boundary ---State boundary

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ESTABLISHING THE RELEVANT FRAMEWORK FOR EFFICIENT RESEARCH ACTIVITIES IN NIGERIA

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ABSTRACT

Apparently, efficient management of research activities cannot be achieved independent of a similarly well managed economic system in which the activities are carried out. This implies that an efficient research system cannot exist in an inefficient production system. This is because a research system is indeed only a subsystem of the production system in an economy. Moreover, the efficiency of a research system depends to a great extent on many interactive linkages between the research system and the other subsystems in an economy. The quality of a production system depends directly on the quality of the knowledge applied in it. The more advanced the knowledge applied, the more structured and efficient the system becomes and the more efficient its research subsystem correspondingly becomes.

The unstructured nature of the Nigerian artisan/ craft production system, explains the lack of functional relationships within the research subsystem and the rest of the economy and its inefficiency. To ensure that research activities become efficient in Nigeria, efforts must first be devoted to organizing the more common knowledge for the establishment of a more structu4red production and research systems. It is within this new framework that relevant research linkages can be established to facilitate efficient research activities.

1. INTRODUCTION

Research is the act of re-examining a problem situation, production for example, with a view to obtaining extra-ordinary knowledge, achieving a better understanding of the situation and solving the problems in it. This suggests that the role, effectiveness and efficiency of a research system depend of the system in which the research system is situated. Our definition of the research process suggests that research units are traditionally subsystems of production systems. This in turn suggests that the establishment of the production/ service system usually precedes the existence of the research subsystem. What does history say?

Mees (1920) distinguished between divergent and convergent laboratories. He defined convergent laboratories as those which focus on a group of related problems and defined those which focus on many unrelated problems as divergent. Early university laboratories in Europe were divergent in character, but eminent professors later gathered around themselves large groups of students who were trained in research methods by assisting the professors in elucidating problems in particular fields which they made peculiarly their own convergent laboratories (Hill, 1947). Examples of convergent laboratories in Europe are the Cavendish Laboratory at Cambridge under J. J. Thomson for electron studies and later under the leadership of Lord Rutherford for radioactive and nuclear studies; the development of the ultracentrifuge and its application by Upsala by the Svedberg, etc.

As in Britain, it was not until the first World War (1914 – 1918) with the threatened shortage of vital dyes, drugs, glass, etc. from Germany sources that the Americans awoke to the necessity for intensive scientific research (Hill, 1947). Teachers in many universities in the United States in the 1940s did not have PhD's and did not do research (Ostrach, 1990). But the US had experimented with many different forms of cooperative research for industry. Cooperative industrial research seemed to have started first in the United States late 1880s when the can sugar producers of Louisiana found themselves threatened by the competition of the beet sugar producers. The beet group was using scientific methods of extraction. The cane sugar producers decided to meet the challenge by the same method and established a sugar experimental station first at Kenner and later at Audubon on the outskirts of New Orleans. The shortage of trained men to staff the experimental station led to the undation of the Audubon Sugar School in 1891 which was run in conjunction with the experimental station.

Most of the traditional or heavy industrial processes and equipment were developed in the United States around the turn of the twentieth century. The traditional industries include steel, machine tools, automotive, and electrochemical industries. These developments were essentially empirical or semi-empirical (Ostrack, 1990). Traditional engineering education then was aimed at transmitting "current practice" to the students.

This short history shows that indeed European and American nations achieved industrial revolution (maturity) before the establishment of their research systems. We can assume that the same sequence was observed in the Asian systems. Why was that the situation? Was it by accident? This is because no well defined form and relationships really become established in an economy before industrial maturity. Industrial maturity establishes pertinent production linkages and relationships.

A typical modern economy may be subdivided into the following four sectors: Government Sector (GS), Real Sector (RS), Financial Sector (FS) and External Sector (ES). The GS would include institutions, establishments and activities devoted to managing government revenue and expenditure and public debts. The RS would be concerned with managing domestic production, managing unemployment and domestic prices and managing social activities like educational, health, water resources development population activities, environmental protection activities, etc. The FS would be made up of institutions, establishments and activities concerned with managing monetary affairs and credit development, interest rates, money and capital markets. The ES would be the one concerned with international economic development, international financial development, etc.

The following six interactive linkages are also expected in a typical modern economy:

1. GS-RS: This must exist to enable government determine the support it must give to promote high domestic production, reduce unemployment and prices and sustain adequate social services. This linkage is also indispensable to the effective collection of government revenue from personal and corporate taxes.
2. GS-FS: this linkage is necessary for the development of monetary and credit facilities and regulation of interest and capital markets. This linkage is also important to managing government revenue, expenditure and debts.
3. GS-ES: This is important to the effective management of import and export relationships.
4. RS-FS: This linkage is important for effective production and financial systems. Production is indispensable to the existence of a healthy financial system, so is the supply of financial resource important to production activities.
5. FS-ES: this is important to sustaining effective and efficient import/ export activities in the economy.
6. RS-ES: This is important to import/ export activities in the economy. A strong production base in the RS is the foundation for a virile export scheme. Apart from these inter-sectoral linkages, intra-sectoral linkages are also important to sustaining a modern economy.

The more common complaint in research systems today is that of dwindling funds. No one seems to be interested in inquiring into the basis of the dwindling funds. It is not important that research work should be used to solve problems so as to convince politicians of the need to fund research?

The common reason being advanced by technologically advanced nations (TANs) for the dwindling fund is that spending cuts are part of the effort being made to reduce budget deficits. One of the explanations for the vanishing expenditure on social services including education in technologically backward nations (TBNs) is indebtedness. One question that readily comes to mind is, what are the causes of the budget deficit problems being experiences in TANs and indebtedness in TBNs? Attendant to the problems leading to string budgeting in the world today are those of co-existent decreasing or low productivity, high unemployment and high inflation. Are these not the concern of technology-related research? It appears that the social scientists have given up about these problems. Is it true that technology-related research and social science research are quite independent activities as cursory observation shows? With funds for educational and other social services research dwindling, it does not appear that military research and activities are experiencing the same problem. Galbraith (1967) remarked that the industrial system requires a large public sector for the stabilization of aggregate demand in agreement with Keynesian theory which suggests that the use of deficit budgeting to stimulate aggregate demand. Galbraith also added that the industrial system planning reaches its highest state of development in conjunction with modern military procurement sustained by large sums of money easily obtained by a process that is routine. In the United States for example, he noted, "it requires more effort by a President to reduce military expenditure by 20% than to increase it by like amount". Education at best enjoys the sixth position in Nigeria's priority. It is therefore not likely that military budgets and related activities have not been experiencing decreasing fund problems. Is this important to technology-related research?

It has been observed that the convertibility of military technology into civilian applications is rather low (Domas, 1991). It has also been observed that developing nations spending large amounts of funds in purchasing and assembling military arsenals are only wasting time because no nation really purchases military capability (Ogbimi and Adjebeng-Assem, 1994). Human experience shows that lasting military strength derives from a strong economic base. Is it not important to let politicians know these? Who is to do it, the technology-related researcher or the social scientist?

The objective of this paper, therefore is to examine the Nigerian research system in relation to its understanding of the close relationship between the production and research systems in an economic system. It is also to examine it in relation to the presence of the linkages necessary for the efficient functioning of the system and the proper flow of funds into the system. These would provide the basis for suggesting ways for improving the efficiency of the system.

2. THE NIGERIAN PRODUCTION/ RESEARCH SYSTEM

The Nigerian production system in government circles has two descriptions. First, it is seen as s four-sector economy: Government Sector (GS), Real Sector (RS), Financial Sector (FS) and the External Sector (ES). Second, it is seen as a two-component system: the Formal and Informal Sectors (Central Bank of Nigeria, 1994). The four-sector view follows the pattern discussed above. The formal sector is the component made up of the industrial organizations owned by foreigners and a few Nigerians as joint ventures. The formal sector probably contributes about 3 percent to Nigeria's Gross Domestic Product (GDP). It is highly import dependent. Each market is made up of a few firms; no basis for competition. For example, two companies produce wheat flour. No serious production takes place in the formal sector, therefore the organizations do not have reasons for interacting with and supporting the research community. The Nigerian economy remains an artisan/ craft production system. In the absence of a matured production system, the six inter-sectoral linkages discussed above are virtually absent and so are the intra-sectoral linkages.

The Nigerian research system is composed of four sub-systems. These are: Educational Research System (ERS), Research Institutes System (RIS), Ministerial and Extra-Ministerial Research System (MEMRS) and the Formal Sector or Private Sector Research System (PSRS). The ERS is based in educational institutions, especially Universities and Polytechnics. There are about 40 each of Universities and Polytechnics. The principle in University is "publish or perish". It is less so in Polytechnics. University education is also strongly research-biased; final year undergraduates and M.Sc. and Ph.D. candidates must produce research thesis as partial fulfillment of the requirements for their degrees. It is so in Polytechnics too. The ERS as such, carries out a lot of research activities every year. University and Polytechnic education dates back to the 1940s in Nigeria. Virtually every academic in Universities and Polytechnics believes he is an able consultant and every University and Polytechnic has a consultancy service to offer. Yet their impact is not obvious, the nation's productivity remains very low. There must be a reason.

Thee problem in Nigeria has to do with the poor understanding of the close relationship between the production system and the research subsystem in an economic system. The emphasis is on the laboratory exoterics, not the national economy. The linkages are not understood, and research works are rarely well articulated towards transforming the artisan economy. Most Nigerians are expecting foreign investors to build structures to supplant the indigenous artisan system. This, unfortunately is not possible. But this is the consideration influencing research plans the most. The ERS also lacks the confidence to address national problems; publication in international journals are more revered (Ogbimi, 1990). No critically examined development theories guide research yet.

The RIS is research institute-based. The institutes have specific mandates. This system dates back to 1924 when British government built West African Cocoa Research Institute (Koleoso, 1989). There are no 26 national research institutes and 3 international research institutes in Nigeria. The activities of these institutes are coordinated by the Federal Ministry of Science and Technology. The emphasis of these institutes is on the development of crops. The emphasis on industrial development and medical research is increasing. The institutes have made some progress in developing some hybrid crops, but their potential is limited by their organization.

The MEMRS are based in Ministries and other public agencies. These are largely involved in social science research aimed at managing the economy. This is the closest system to the government. The more active and well-known ones are about ten, but there may be fifty others hidden in the ministries and other public agencies. The view among the management cadre of this group, judging from personal contacts is that social science research does not need any interaction with technology-related research groups. Yet they make pronouncements on scientific issues like productivity, employment/ unemployment, inflation, industrial management and other related matters. This probably explains why these crucial issues that influence all other activities in an economy, including the flow of funds into research activities are, today, not receiving the attention they deserve. It is clear from recent analysis of the co-existent problems of low productivity, high unemployment and high inflation (Ogbimi, 1995) that these problems are indeed technology-related ones.

The PSRS is based in the Organized Private Sector (OPS). It is certainly the weakest system because no serious production takes place in the OPS in Nigeria. There is also no serious intellectual work in the OPS. Professional economists, accountants and bankers in the OPS rarely have time for any serious brainwork.

There are about 200 firms in the OPS involved in formula production. Much of what is being called research in these establishments may at best be more quality control or routine data gathering activities.

3. RECOMMENDATIONS

Many researchers have probably not realized that there is a close relationship between the state of an economy and its research subsystem. Consequently, the prevalent belief among researchers, those in Nigeria especially, is that it is the funds committed to research or the intensity of research per se, that counts, not the efficiency or the relevance of the economic system.

It is probably for the foregoing reasons that Nigerian researchers do not care much about the relevance of their efforts to solving the broad problems confronting the national artisan economy. The low impact of knowledge available in the Nigerian economy on the national life is a consequence of the near complete absence of the relevant linkages in the Nigerian production and research systems. This explains the low efficiency of the Nigerian production and research systems.

Because the establishment of the production system in an economic system always precedes that of the research, researchers in Nigeria should increase the proportion of applied research and reduce esoteric studies. In addition, because the coordination of technology-related research is very important, it should be intensified. Yet it is even more important that the entire research system in an economic system be well coordinated. Therefore, efforts should now be geared toward coordinating the activities and link them with those of production in the indigenous or informal sector. Efforts should also be increased toward establishing the necessary linkages among the four subsystems in the research system.

Learning something new is the primary basis for initiating a fundamental change. Because the Nigerian educational system apparently has not been addressing the nation's problems, it is hereby suggested that the Nigerian University Education curriculum should be modified to incorporate into it more of "teaching as practiced" and "teaching for the improvement of current practices", so that the impact of learning can become more evident in national life in Nigeria. This is how the relevant framework for efficient production and research can be established speedily in Nigeria.

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