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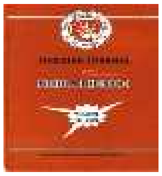

ASSESSMENT OF THE WATER CONSERVATION POTENTIAL AND MODE OF APPLICATION OF COCONUT *(COCOS NUCIFERA)* HUSK HYDROGEL ON SOIL CULTIVATED TO COCONUT SEEDLING

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ABSTRACT

Coconut husk cellulosic-polyacrylonitrile hydrogel was synthesized in aqueous solution. Saponification of grafted copolymer was done by reaction with sodium hydroxide followed by methanol precipitation. The reaction was confirmed using FTIR and characterized in terms of water retention value (286g/g) and de-swelling ratio (83.16%). Soil samples collected were prepared and analyzed for physico-chemical properties in the laboratory using standard techniques. The water conservation properties of the hydrogel –soil mixture samples in which coconut seedlings have been planted were measured as a function of the mode of hydrogel application (Variables A-D), loading (W_1-W_4) and compared with the values obtained in the control in which hydrogel was not added. The hydrogel showed significant improvement in soil water conservation and water retention ability. The results of the hydrogel mode of application showed that there was increase in the ability of the soil to retain moisture and also there was significant increase in the growth performance of the coconut seedlings.

KEYWORDS: Hydrogel, soil, coconut husk cellulosic, polyacrylonitrile, Coconut seedling.

INTRODUCTION

Growth and productivity of coconut nurseries are influenced by external factors such as rainfall, temperature, sun shine duration, relative humidity and the management practices like irrigation and nutrition. The optimum weather conditions for good growth and nut yield in coconut are well distributed annual rainfall between 130 and 230 cm, and mean annual temperature of 27°C among others. The average weather condition in Nigeria results in moisture stress of coconut nurseries and palms, aggravated by soil water deficit, leading to poor nut yield. Drought stress affects coconut production in almost all coconut growing countries, since it is mainly a rainfed plantation, Coomas, (1975); Mathes, (1988); Bhaskara Rao et al, (1991)

Drought and desertification are at the core of serious challenges and threats facing sustainable, agricultural development in Africa, Andreas (2005).. These problems have far reaching adverse impacts on human health, food security, economic activity, physical infrastructure, natural resources and the environment, and national and global security.

Although drought has several definitions, the central element in these definitions is water deficit. Farmers are struggling, money has been lost, livestock are suffering, and the landscape shows the all-too-familiar brown grass and cracked earth.

The underlying cause of most droughts can be related to changing weather patterns manifested UNCCD (2004) through the excessive build up of heat on the earth's surface, meteorological changes which result in a reduction of rainfall, and reduced cloud cover, all of which results in greater evaporation rates. The resultant effects of drought are exacerbated by human activities such as deforestation, overgrazing and poor cropping methods, which reduce water retention of the soil, and improper soil conservation techniques, which lead to soil degradation. However, Superabsorbent polymer hydrogels have a critical role to play here.

Superabsorbent polymers (SAPs) or hydrogels are loosely cross-linked, three-dimensional networks of flexible polymer chains that carry dissociated, ionic functional groups. They are polymers which are characterized by hydrophilicity containing carboxylic acid, carboxamide, hydroxyl, amine, imide groups and so on, insoluble in water, and are cross-linked polyelectrolytes, (Zohuriaan-Mehr *et al.,* 2008). Because of their ionic nature and interconnected structure, they absorb large quantities of water and other aqueous solutions without dissolving by solvation of water molecules via hydrogen bonds, increasing the entropy of the network to make the SAPs swell tremendously. Water is brought into the network through the process of osmosis and quickly journeys into the central part of the polymer network, where it is reserved. This is when the hydrogels act as absorbing agents and take on the outward appearance of a gel. Amazingly, hydrogels can absorb up to 500 times their weight in water, and when their surroundings begin to dry out, the hydrogels, gradually dispense up to 95% of their stored water. When they are exposed to water again, they will rehydrate and repeat the process of storing water. This process can last up to seven years, when the biodegradable hydrogels decompose. These properties are what make hydrogels attractive to the agricultural world.

Although many nurseries have shown an interest in hydrogels, not as many farmers in the developing countries have. We were interested in assessing if the hydrogels would make a significant difference in conserving water and retaining the moisture in the soil used for coconut nursery.

MATERIALS AND METHODS

Materials

Coconut husk (Cocos nuciferous) were obtained from the Badagry sub-station, Nigerian Institute for Oil Palm Research, Nigeria, the soil used was obtained from the institute and coconut seedlings obtained from the institute. polyacrylonitrile (PAN) was supplied by B.D.H. as reagent grade

Preparation of the Coconut husk Cellulosic material

Matured coconut husk were harvested and cut into small strips with saw blade. The strip material was grounded using a mechanical grinder. The material was then placed in a shaker with sieves to pass through a 425-μm mesh sieve yet retained on a 250-μm mesh sieve. The resulting material was placed in glass jars labeled with appropriate designation for the analysis.

The cellulosic was isolated using the method described in literature (Brendel, 2000).

Characterization of the coconut husk and soil

The coconut husk were characterized in terms of the lignin content, holocellulose content, ash content, hemicellulose content and cellulose content determined using methods described in literature, ASTM D1106-96, 1104-56,1102-84, 1103-60. The elemental content were determined using instrumental methods. The results are as presented in Table 1.

The soil samples were characterized as follows: Bulk density was measured by core method. Soil pH was measured in 1:1 soil-water ratio. Soil organic carbon, was estimated by combustion at 840°C, while total nitrogen was obtained by microkjeldahl method. Cation exchange capacity, was measured using ammonium acetate leaching at pH 7.0. Available phosphorus was determined by Olsen method, The results are as presented in Table 2.

Preparation of the hydrogel

A general procedure for alkaline hydrolysis of coconut cellulosic-PAN mixture was conducted as follows. Coconut cellulosic solution was prepared in a 1-l reactor equipped with mechanical stirrer (Heidolph RZR 2021, three blade propeller type, 300 rpm), and gas inlet. 1g Coconut cellulosic was dissolved in 30.0 ml of distillated degassed water containing 1wt. % of acetic acid solution. After complete dissolution of coconut cellulosic, 10 wt. percent of sodium hydroxide was added to the solution at 90 ^{o}C. The mixture was allowed to stir for 120 min. 1g polyacrylonitrile was dispersed in the reaction mixture to saponify for certain times and temperatures. During the saponification, NH_3 gas was evolved and a color change from red to light yellow. This discoloration was an indication of the reaction completion. The pasty mixture was allowed to cool to room temperature and neutralized to pH 8.0 by addition of 10 wt % aqueous acetic acid solution. Then, the gelled product was scissored to small pieces and poured in ethanol (200 mL) to dewater for 5 h. The hardened particles were filtered and dried in oven (50 ^{o}C, 10 h). After grinding, the powdered superabsorbent hydrogel was stored away from moisture, heat and light, (Pourjavadi and Mahdavinia, 2006)

Swelling and de-swelling measurements of the hydrogel

A tea bag (i.e. a 100-mesh nylon screen) containing an accurately weighed 0.5g powdered sample, with average particle sizes of 250-350μm, was completely immersed in a 200ml distilled water and allowed to soak for 3 h at room temperature. The tea bag was hung up for 15 min in order to remove the excess fluid. The equilibrated swelling was measured twice using the following equation, Lanthong et al (2006), and expressed as a water retention value (WRV) calculated in grams of water per grams of dry polymer.

Water retention value $(g/g)=\frac{(W_2-W_1)}{W_1}$

(1)

Where, W_2 and W_1 are the weights of water swollen hydrogel and dry absorbent in grams, respectively.

The de-swelling water ratio of the sample was evaluated from the following equation:

De-swelling water ratio (%) = $=\frac{(W_t)}{W_{to}}$ x 100

(2)

where W_{t0} and W_t are the initial weight of the fully swollen sample, and the weight of sample at de-swelling time (t), respectively. The results are as presented in Table 3.

Infrared analysis

IR spectra of cellulose-PAN mixture and hydrogel were recorded on an ABB Bomem MB-100 FTIR spectrophotometer and as presented in the spectral sheet in Figure.1.

Soil-Hydrogel mixing procedure

Measured quantities of the hydrogel (3.0, 6.0, 9.0, 12.0g) designated as W_1, W_2, to W_4, were uniformly blended with 2kg soil by according to the variables below, placed in five-liter polyethylene plastic containers and holes were drilled at the bottom of each container to simulate the drainage that would occur in a real garden. The controls and variables were set up as follows:

Control A: No hydrogels—watered once at beginning of experiment; Soil moisture retention control.
Control B: No hydrogels—watered regularly throughout experiment; Water conservation control.
Variable A: A one-inch-thick application of hydrogels at the surface of the soil
Variable B: A one-inch-thick application of hydrogels in the root zone
Variable C: A one-inch-thick application of hydrogels below the root zone
Variable D: An application of hydrogels spread throughout the soil, from the surface to one inch below the root zone.

One coconut seedling was planted in the center of each container. The soil was irrigated with water slowly and the volume of water required to saturate the soil to field capacity was recorded. The plants and soil had their first and only drink of water (except for Control B), and the drought began. Control A represented soil moisture retention. It was watered once. This control was used to identify the day when the percentage of soil moisture was no longer capable of supporting plant growth—the day it hit the wilting point. Control B served as a water conservation control. It was watered regularly (weekly) and was used to identify the amount of water needed in normal conditions to sustain the plants at a proper percentage of soil moisture. Soil samples from the container were collected at weekly interval and analyzed for moisture content determined by oven-drying the soil sample at 110°C. This was done every week for 12 weeks. Biweekly observations of the appearance of the plants were recorded.

In all, 6 treatments per set (Hydrogel, 4 variables and two controls) were replicated and arranged in complete randomized block design.. Biometric data on height, turgor, plant health and leaf population of the experimental plants were recorded at biweekly intervals. The total amount of water used for irrigation was determined upon completion of the study. Data were analyzed by Analysis of Variance (ANOVA).

RESULTS AND DISCUSSION

Characteristics of the coconut husk and Cellulose yield

Table 1 shows the Characteristics of the coconut husk and the extractive cellulose yield.

In general, the alpha-cellulose content in coconut husk is 40-60%, which is consistent with the reported cellulose content of softwoods (40-62%) . Holocellulose include alpha-cellulose and hemicellulose. Approximately 40-60% of the dry substance in coconut husk is alpha-cellulose.

Hemicelluloses are heterogeneous polysaccharides, like cellulose, most hemicelluloses function as supporting materials in the cell walls, (Coomas, 1975). Coconut husk lignin is built up from three phenyl-propane units, p-coumaryl, coniferyl and sinapyl alcohols interconnected through biosynthetic pathways, (Bhaskara Rao et al, 1991).

Table 1: Characteristics of the coconut husk and the extractive cellulose yield

Ash (wt%)	**Lignin (%)**	**Hemicellulose (%)**		**Cellulose (%)**		**Holocellulose (%)**		**Cellulose yield (%)**
38	29	44		21		65		42.6
Element(mg/kg)	Al	Ca	Mg	Na	K	Fe	P	Si
Content	150	480	530	1800	2400	190	50	3000

The lignin values of 10-20% place coconut husk at the low end of the normal range or 11-27% reported for non-woody biomass, and closely resembles the ranges reported for softwoods (14-37%) and hardwoods (17-30%) . The lignin content of coconut husk contributes to its high heating value. Ash is a term generally used to refer to inorganic substances such as silicates, sulfates, carbonates, or metal ions. The elemental content of the husk is significant, as it would help in increasing the soil nutrient for the growth of coconut seedlings.

Physico-chemical characteristics of the experimental soil before planting

Table 2: Physio-chemical properties of the soil sample

Properties		Value
Depth, cm		30
pH		8.3±0.1
Conductivity,µs ©		2720±602
Bulk Density(g/ml)		1.56±0.05
Moisture content (%)		7.2±0.1
Particle size	%clay	10.80±0.02
	%silt	7.80±0.01
	% sand	95.40±0.02
Acidity		3.5±0.1
Organic Carbon (%)		1.5±0.1
Available nitrogen,(kg/ha)		55.04±0.02
Available phosphorus,(kg/ha)		23.78±0.04
Available potassium (kg/ha)		18.31±0.01
Calcium content,(mg/Kg)(CC)		608±10.1
CEC (m.e/100g)		5.2±0.1

Table 2 shows the physico-chemical properties of the Soil. The result shows that the soil is alkaline and Textural analysis in table 2 showed the preponderance of sand fraction (95.40%), followed by clay (10.80%), then silt (7.80%), thus classifying the soil as sandy loam soil. This is corroborated by the soil bulk density (1.56g/cm^3) which is an index of the textural nature of the soil.

Hydrogel characteristics

The hydroxyl groups of the coconut husk cellulosic substrate were converted to corresponding alkoxide ions using a sodium hydroxide solution. Then, these macro alkoxides initiate a cross-linking reaction between some adjacent polyacrylonitrile pendant chains. This reaction leads to intermediate formation of naphthyridine cyclic structures (including imine, -C=N-, conjugated bonds) with a deep red color. The intermediate was then hydrolyzed using a residual sodium hydroxide aqueous solution to produce hydrophilic carboxamide and carboxylate groups, with a resulting color change from red to light yellow. This sharp color change was used as an indication to halt the alkaline treatment.

FTIR spectroscopy was used to confirm the chemical structure of the hydrogel (Figure 1). In thespectrum of the St-PAN physical mixture, the band observed at 2242 cm−1 can be attributed to stretching of the –CN group of PAN (Figure 1a). The hydrogel comprised a cellulosic backbone with side chains that carry carboxamide and carboxylate functional groups, which are evidenced by 3 new peaks at 1407, 1556, and 1675 cm−1 (Figure 1b). These peaks are attributed to C=O stretching in the carboxamide functional groups, and symmetric and asymmetric stretching modes of the carboxylate groups, respectively, (Silverstein and Webster, 1998). The stretching band of–N H overlapped with the -OH stretching band of the cellulosic portion of the copolymer.

Table 3: Characteristics of the hydrogel

Characteristics	Results
Water retention value (g/g)	286±8.5
De-swelling ratio (%)	83.16±0.02

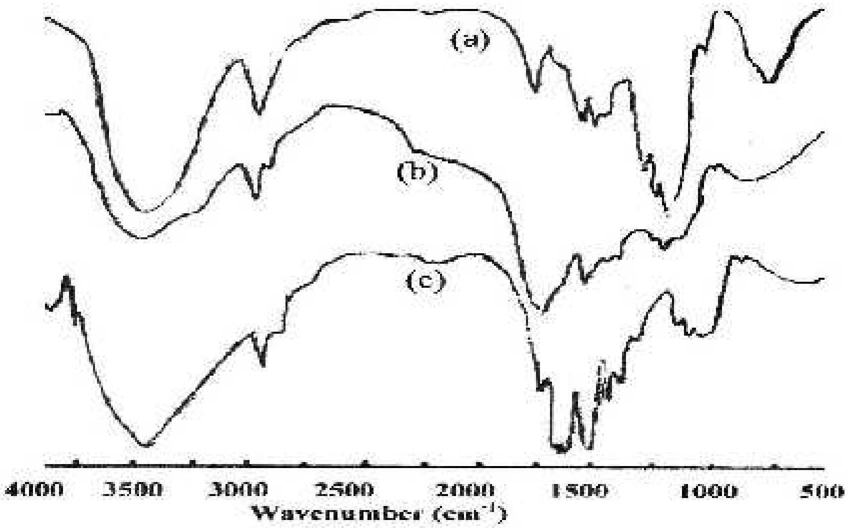


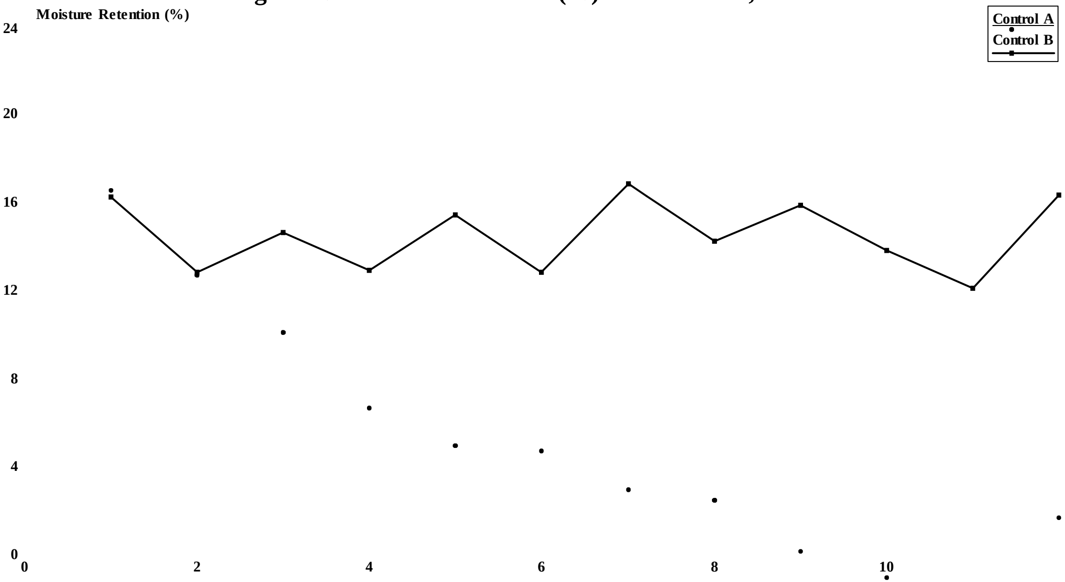
Figure 1. FTIR spectra of (a) the physical mixture of Coconut husk cellulosic and PAN, and (b) the cross linked cellulosic-poly (NaAA-co-AAm) hydrogel.

Influence on the growth of coconut seedlings, and water conservation of the soil

Figure 1 2, 3, 4 and 5 show that moisture content after irrigation from W_1 to W_4 due to the application of the hydrogel to the soil, indicating water available to the plant and hence increase growth of the plant. Gehring and Lewis (1980) reported that moisture stress of plants decreased by incorporation of a hydrogel into the medium. Wallace and Wallace (1990) stated that generally the most favourable results for seed emergence and water infiltration came from hydrogel application. Immediately, the difference between the soil samples with hydrogels and the soil samples without hydrogels became evident. The dynamic rate of the water slowed down as it came in contact with the hydrogels. Already it was obvious that the cross-linked polymers were at work absorbing the available water.

Throughout the whole process, the differences between Control A and the variables were highly evident. Our soil is classified as a sandy loam soil, and its capacity to hold water is low. Water passes through all zones quickly and away from the area available to plants. So seeing the water spread through Control A demonstrated the quick absorption rate of the soil. Throughout the 120 days, Control A decreased in moisture rapidly, which affected plant health.

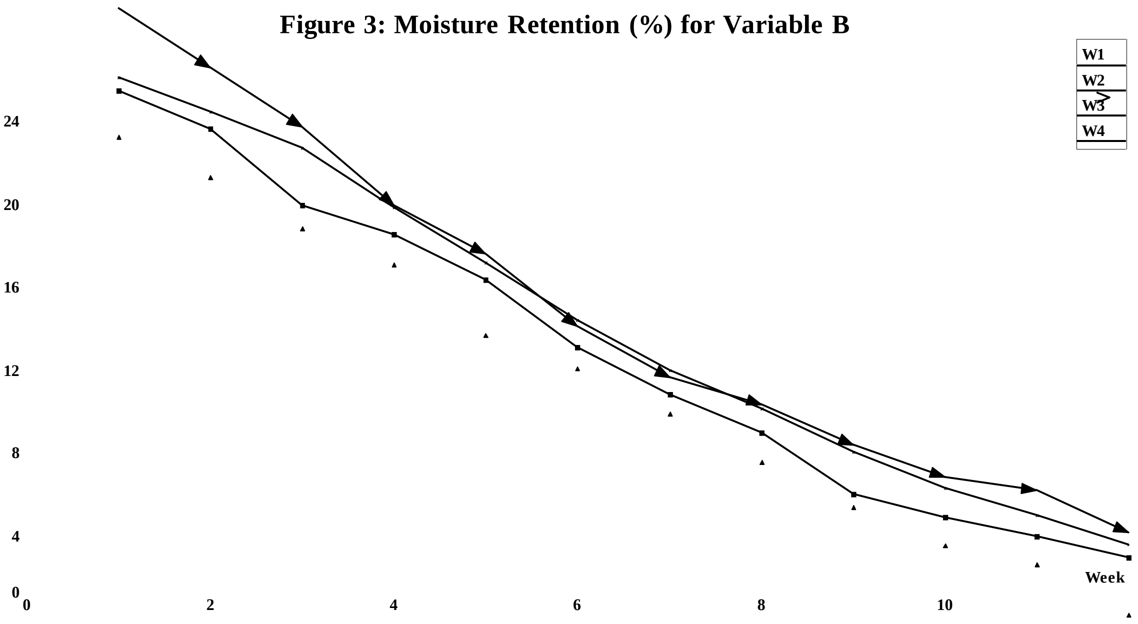
Figure 1: Moisture Retention (%) for control A, and B



Control B showed almost exactly the same results as Control A in absorbing water and retaining soil moisture at the beginning of the experiment (Figure 1) . Of course, the difference was that Control B was watered weekly at the experiment proceeded. Control B showed the amount of water needed to sustain a proper percentage of soil moisture for the plants. Control B needed an additional 1L of water during the experiment to sustain the proper percentage of soil moisture needed by the plants. As water was slowly added to the soil samples, the hydrogels again absorbed water into their "network" to store water for future use by the plants

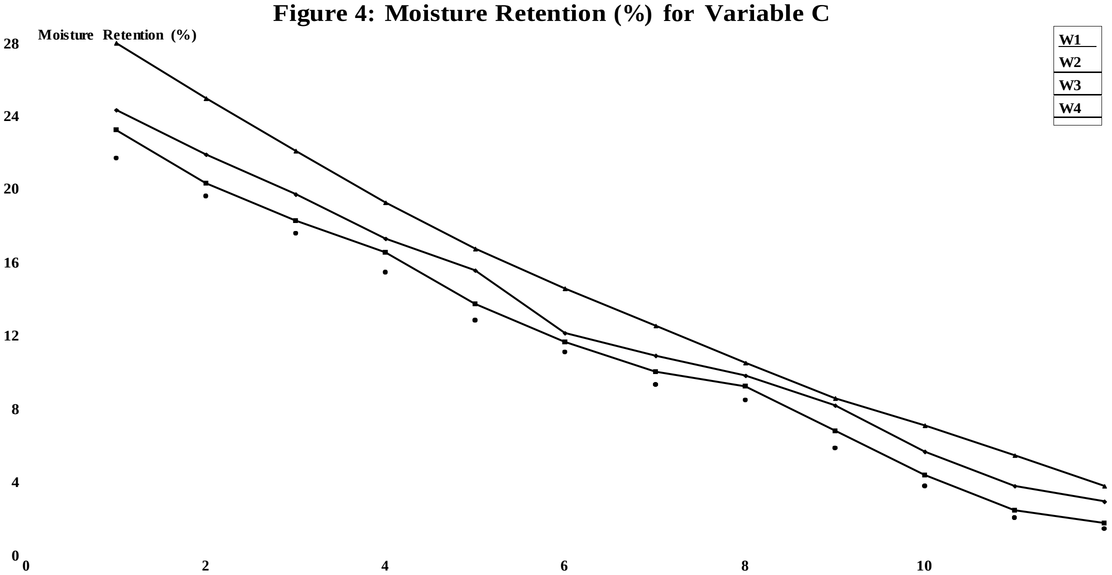
Interesting enough, Variable A,(Figure 2) which contained hydrogels throughout the soil surface, showed the least amount of soil moisture, similar to Variable D. One explanation is that the hydrogels near the surface dried out sooner because of evaporation. Our humidity averaged 30 percent during the experiment. And since water is dynamic and not static, the water could have continued to move to the surface and evaporate, thereby lowering the moisture readings. Variable A retained optimal soil moisture for an additional five days and conserved 0.15L of water during this experiment.

Figure 3: Moisture Retention (%) for Variable B



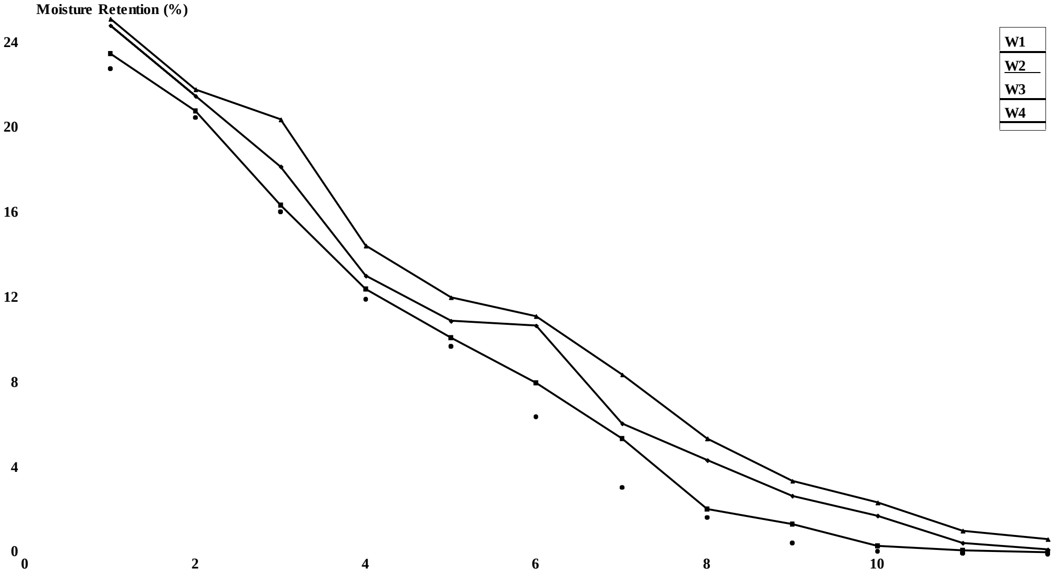
Variable B, which we hypothesized would be the best application, did indeed retain soil moisture and conserved water very effectively (Figure 3). It wasn't until eight days after Control A dipped into the wilting zone that Variable B entered it. Throughout the period of the experiment, the plants thrived, and moisture levels were within an adequate moisture reading until the last two weeks. Variable B conserved 0.3L of water during this experiment.

Figure 4: Moisture Retention (%) for Variable C



Variable C was very effective as it ran its course (Figure 4). Its moisture levels were very close to those of Variable B throughout the 120-day testing period. The difference between the two was very slight. Variable C also retained soil moisture above the wilting point eight days longer than Control A, eliminating the need to water during the testing period. Variable C conserved 0.3L of water during this experiment.

Figure 5: Moisture Retention (%) for Variable D



Variable D (Figure 5) declined more quickly than variables B and C. it is believed this had to do with the rate of evaporation at the soil surface. This evaporation did not allow the stored water in the hydrogels to have a chance to be absorbed by the plants. With the water being so close to the surface, it quickly evaporated into the air.

The results show a definite positive result in moisture retention in all the hydrogel applications, as well as a significant conservation of water. The most effective application of hydrogels was when they were applied in and below the root zone.

Table 4: Biometric observations of the coconut seedlings showing the height and leaf number

Control (2) BIWEEK	Ht (cm)	LN	**W1**	Ht (cm)	LN	**W2**	Ht (cm)	LN	**W3**	Ht (cm)	LN	**W4**	Ht (cm)	LN
2	8.5	2		10.1	2		11.1	2		12.6	3		17.3	4
4	9.5	2		10.5	4		11.5	4		13.6	6		17.9	6
6	10.1	2		11.1	4		11.8	6		15.1	8		19.3	8
8	10.5	3		11.8	4		12.5	8		15.8	8		20.5	10
12	**12.8**	**4**		14.5	**6**		16.4	**10**		18.6	**10**		24.9	**12**

Ht=Height, LN = Leaf Number

Table 5: Physical observations of the coconut seedlings turgor(+/-) for soil-hydrogel mix

Week	Control1	Control2 W1		W2	W3	W4
2	+	+	+	+	+	+
4	+	+	+	+	+	+
6	_	+	+	+	+	+
8	_	+	_	+	+	_
12	-	+	_	_	_	_

+ = high plant turgor, - = occurrence of wilting

Table 4, shows the growth performance of the coconut seedlings in terms of height and leaf number of the plant. The table reveals consistent increase in growth and leaf number, which is expected based on the availability of soil nutrients and water. The results show that there are significant effects of irrigation regime on the height and leaf number. The height and leaf number increase from W_1 to W_4 due to the ability of the soil to make water available to the plant. The control did not show comparable increase in the height and leaf number of the plant. Table 5 shows the plant turgor for soil-hydrogel mix; turgor support plants that do not have woody stems. Plants lacking in turgor visibly wilt, which is the case for the control1 beyound the 4th week. The process of osmosis plays an important part in maintaining the turgidity of plant cells. Water leaves and enters the cell by osmosis. If too much water leaves the cell, then turgor is lost and the cell becomes flaccid. As turgor gives the plant rigidity, loss of turgidity results in the plant wilting.

CONCLUSION

The main aim of this work is to gauge the influence of coconut husk cellulosic--PAN hydrogel on the water conservation of the soil supporting the growth of coconut seedlings in Nigeria, as well as the influence of the mode of hydrogel application on the soil performance under farming condition typical to developing countries.

The soil samples containing hydrogels showed a large margin of water conservation, as well as better retention of moisture compared to the samples that did not contain hydrogels.

The results indicate that there is an improvement in the ability of the soil to retain water by reason of the introduction of the hydrogel, thus, this could become cost effective in irrigation of farmlands in Africa. These results are of interest for the development of hydrogel-based technologies for solving the problem of agriculture and water conservation management in sub-Saharan Africa.

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