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AN ASSESSMENT OF RAIN WATER SUPPLY ON YAM PRODUCTION IN SOUTHWESTERN NIGERIA

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Abstract: The water supply of South-western Nigeria for the cultivation of yam (*Dioscorea rotundata*) was investigated. Six phenological stages of the crop formed the basic unit for the investigation. The experiment comprises of three varieties of yam (Efuru, Ise-osi and Oniyere) and two planting season (early and late).Selected moisture indices were measured daily and processed into ten-day (dekad) average for the 2007 and 2008 cropping seasons following FAO (1977). Descriptive statistics was employed for the analysis. Relating the effective water availability to the indices of moisture adequacy for the growth of the crop, it was found that the agro-climatic moisture indices were optimum during the moisture sensitive stages particularly for early season planting. A comparison of yam production in the study area showed that early planting promotes the growth, development and yield. This confirmed the water supply efficiency of rain-fed agriculture in South-western Nigeria for yam production.

Key words: Actual Water Availability, Crop's Water Consumption, Moisture indices, agroclimatic

INTRODUCTION

Yam apart from being an important source of energy in the diets of millions of people and some livestock, also has cultural and socio-economic significance (Scott *et al.,* 2000). Despite of its importance in Nigeria, yam cultivation is characterized by low technical inputs, low agricultural output and lean financial resources and this has led to declined production (Olasantan, 2007). Hence, yam appeared to be the most costly of all tubers grown in Nigeria. Consequently, there is a drastic shift in demand to a cheaper food staples like cassava, even though the latter is less nutritious. Yam production in the tropics according to Verrnier and Dossou (2000) is sensitive to climatic factor in terms of its variation over space and time than the other environmental factors and moisture remains the most critical agro-meteorological factor for crop production in the tropics. While excessive water supply may lead to inadequate soil aeration, limit the amount of oxygen and increase the formation of compounds that are toxic to plant roots, the water deficiency may not only reduce the yield but also change the pattern of growth (Bello, 1997). Relating these two extremes to the tropics where the ideal situation of a balance water supply for agricultural purposes is lacking, Bello (1997) noted that while too much moisture is harmful to most crops, it is however far less an agricultural problem than drought which is, in fact, the major hydrometeorological factor that poses threats to agricultural activities in the tropics. In the study area, one major persistent problem for agriculture is that of water supply which is manifested by the seasonal and variability of rainfall. Rainfall variability in the area is not limited to seasonal fluctuations but also includes year to year variability in the onset, cessation and duration of the rains which are also characterized by dry spells of unpredictable magnitude. Hence, assessment of water supply for agriculture should form part of the agricultural planning process. With this in mind, the assessment of water supply on yam production in Southwestern Nigeria will be achieved by analyzing water availability and potential water need (potential evapotranspiration) so as to determine the effective water availability that will satisfy water requirement of crop during the different phenological stages and relate this to crop water satisfaction index.

MATERIALS AND METHODS

Description of study area

The research was conducted at the Teaching and Research farm of University of Agriculture along

Alabata road, Abeokuta (7° 15'N, 3°25'E) in Odeda Local Government Area of Ogun State, South Western Nigeria (Fig. 1) during the 2007 and 2008 cropping seasons. The study area is characterized by a tropical climate with distinct wet and dry seasons with bimodal rainfall pattern and mean annual air temperature of about 30°C. The actual rainfall totals during the 2007 and 2008 cropping season were 1177.2 and 1201.6 mm, respectively. The soil at the experimental site was categorized as a well-drained tropical ferruginous soil (A horizon of an Oxic Paleudulf of Iwo series) with 83% sand, 5% silt and 12 % clay with a pH of 6 considered tolerable by yam (Olasantan, 2007).

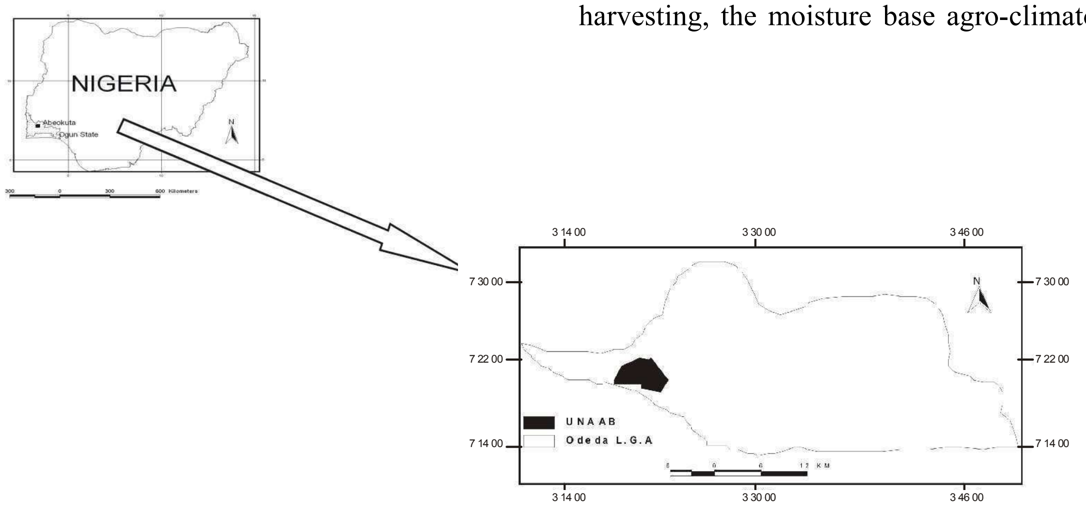

Fig. 1: Location of University of Agriculture, Abeokuta within Odeda Local Government Area in Ogun State, Southwestern Nigeria

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Experimental design and field measurement

The experimental site, comprised of 30 x 60m² land which had previously carried beans *(Vigna sinensis)* and groundnut *(Arachis hypogaea)* intercrop but had been fallowed for over 3 years. The site was cleared manually using cutlass in November 2006, in preparation for the 2006-2007 cropping following the popular practice by the farmers in the study area. This period marks the preparatory period for the cultivation of early yam planting (E) in the study area. However, the plot for late yam planting (L) was also prepared. Yam mounds of height 60cm and spaced 1.5 x 1.5m² a walk way of 1m between adjacent rows were made manually using African hoe. Three local white yam, *Dioscorea rotundata* cultivars (Efuru, 'A_1; Ise-osi 'A_2; and Oniyere 'A_3) were used. Selection of the cultivars was on their acceptance in the University's extension villages around the study area. Each yam cultivar was cut into yam sets weighing an average of 550grams, and planted at an average depth of 15cm on mounds. After sprouting, the yams were staked to about 3m high and the vines were trained regularly. No fertilizer and insecticide were applied and all plots were regularly hand weeded. In other to relate the moisture indices of the study area to the climatic requirements of yam from planting to harvesting, the moisture base agro-climatological indices for the crop growth were measured according to phenological stages of the crop. In this study, six developmental stages of yam growth cycle form the time-scale for which the collected data have been processed, this includes planting, emergence, vine enlongation, vegetative, bulking and senescence. During each of the phonological stages, daily observation of air temperature (°C), wind speed at a height of 2m (ms^{-1}), rainfall (mm) were made at meteorological enclosure adjacent to the experimental field. Other climatic parameters measured were open water evaporation ,'E_O' in mm determined according to Penman's (1948) formula, actual water availability (AWA, mm) and consumptive water used by the crop (ET_{crop}) in mm is determined as follow:

$$ET_{crop} = K_{CO} \times E_O \text{ mm}$$

Where K_{CO} = Crop coefficient

K_{CO} otherwise referred to as the relative evaporation is expressed as ET. E_O^{-1}, where ET and E_O were measured parameters. The crop coefficients, (Kco) values, represent the crop type and the development of the crop. The crop coefficients, (Kco) value for yam in this study were adopted from FAO (1977) for tuber crops. Actual Water Availability (AWA in mm) is taken as the difference between actual precipitation and crop water requirement,

$$AWA = P - ET_{crop}$$

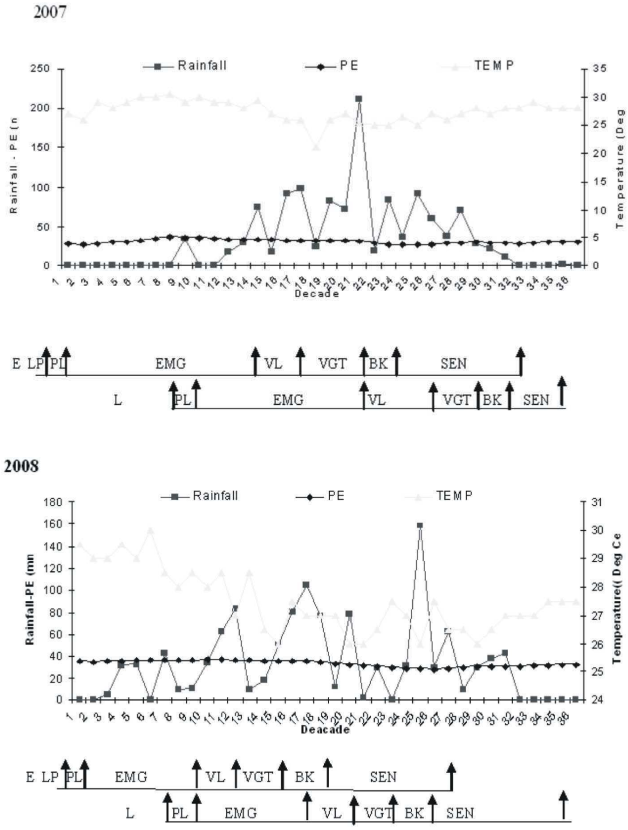
AWA (Wolfgang, 1981) is equivalent to available rainfall (P) plus change in store water and this in turn correspond to actual evaporation. Therefore for periods when P is less than potential Evapotranspiration (PE) AWA = ET_{crop} but for periods where P is greater than $ET_{crop,}$ AWA = P, since in this case actual Evapotranspiration (AE) = ET_{crop} while there is virtually no depletion of soil moisture. The quotient of AWA and WR enable a determination of the degree of humidity which is tolerable by a cultivated plant during the growing season, and allow sub-division to be applied between arid and humid environments. Wolfgang (1981) set an aridity limit at 1.0 and a critical humidity limit at 2.0. Therefore the moisture supply for yam in this study was regarded as supra- optimum for an AWA:WR ratio above 2.0, optimum for a ratio between 1.0 and 2.0 and deficient for a ratio below 1.0.

Climatic parameters were not measured directly at the experimental site but were estimated using meteorological tables (Doorenbos and Pruitt, 1984). The Water requirements satisfaction index (WRSI) indicates the extent to which the water requirements of the annual crops have been satisfied in a cumulative way at any stage of the crop growing season. The WRSI was estimated following the procedure of FAO (1977). The result of yield from experiment and the yield obtained from farmers in University's extension villages around the study area, the data gathered from Ogun State Ministry of Agriculture and Ogun state Agricultural Development Program were compared to ascertain the effectiveness of model. The yield from farmers in University's extension villages around the study area were determined from questionnaire administered during the two experimental years.

RESULTS AND DISCUSSION

Dekadal rainfall, potential evapotranspiration and air temperature distribution for 2007 and 2008 cropping seasons were related to the phenological growth and development stages of white yams (Dioscorea rotundata) in Fig 2. Temperature varied between 21°C and 30.5°C in the both cropping season. The temperature distribution during the phenological stages of 2007 cropping season shows that temperature was higher during the emergence and early vine elongation periods than the other periods for setts planted during early planting (E). Mean decadal air temperature during the 'E' planting ranged between 26 and 30.5°C during the emergence period, 26 and 27°C during vine elongation and 21°C to 27°C during vegetative period and remained at 25°C during bulking period. The lowest range of temperature between 21- 27°C was observed at the vegetative period. However, the temperature ranges for the late planting 'L' at these phenological stages were lower. The temperature distribution during 'L' planting phenological stages ranges between 21-28°C. Mean decadal air temperature in the 2007 "L" planting ranged between 21 and 27°C during the emergence period which coincided with the vegetative period for 'E' planting date. Other phenological stages were observed to have remained at a range of 26 - 29°C. However for 2008 cropping season, the temperature was high during the planting, emergence and early vine elongation periods than the vegetative, bulking and senescence period at early planting (E). Mean decadal air temperature ranged between 27 and 30°C during the emergence period, 27 and 28.5°C during vine elongation and fell drastically to between 26 and 28°C during vegetative period. During bulking period, mean temperature was 27°C. The lowest range of temperature between 26- 27°C was observed at the senescence. Unlike the high temperature range during the planting, emergence and vine elongation periods at the 'E' planting, the temperature ranges for the late planting (L) at these phenological stages were lower. The temperature distribution during the 'L' planting phenological stages ranges between 26-28.5°C. Mean decadal air temperature in the 2008 'L' planting ranged between 26 and 28.5°C during the emergence period and remained at a range of 26 - 27.5°C during vine elongation and the other phenological stages which relatively compared with the range observed at the senescence for the 'E' planting date.

The relationship between moisture based agro-climatological indices, rainfall (P) and potential evapotranspiration (PE) during the experimental year 2007 and 2008 shown in Fig 2. The humid period was observed to be between the 14th dekad and the 30th dekad for 2007 cropping season. This humid



LP = Land preparation, E = Farmer's Conventional Planting dates for early cropping season, L = Farmer's Conventional Planting dates for late cropping season EMG = Emergence, VL = Vine elongation, VGT = Vegetative, BK = Bulking SEN = Senescence.

Fig. 2: Mean decadal rainfall, potential evapotranspiration and air temperature distribution at different phenological stages of white yam

period coincided with the vine elongation to senescence periods for the early planting (E). However, for the late planting (L), the humid period extends from planting to vegetative period of yam. Whereas in 2008 year, the humid period was between the 11th dekad and the 32nd dekad. This humid period coincides with the vine elongation to senescence periods, though there are marginal moist period in the 5th and 8th dekad which favours the emergence for the 'E' planting. However, for the 'L' planting, the humid period extends from emergence to senescence period of yam.

Fig. 3 shows the pattern of rainfall (P), potential evapotranspiraton (PE), actual water availability (AWA) and water requirement (WR) distribution in relation to crop growth stages of white yam for 2007 and 2008 experimental years. It was observed that AWA and rainfall distribution were highly variable. An investigation into the moisture adequacy for yam during the 2007 cropping seasons shows that moisture was grossly inadequate for yam growth from end of planting to emergence period (1st – 13th dekad) for the setts planted during early planting (E). It was also observed that by the 13th dekad when the AWA was inadequate for the requirement of crop, the rainfall has started to satisfy the water requirement of crop. The long term moisture stress which was as a result of short fall in AWA encountered prior to onset of rainfall during the emergence period particularly for the 2007 experimental year was observed to cause loss of setts and disparity in emergence which led to growth retardation and reduction in tuber yield. This was badly felt by most farmers in the area that depended solely on the yam calendar for planting. AWA from figure started to meet up with water requirement at the 15th dekad which marked the vine enlongation period. However, during this long moisture stress period, the down pour of the 10th and 15th dekads were able to replenish the deficiency at the root zone of the crop as a result of infiltration into pore spaces in the soil which could prevent total seedling damage of yam for the early season planting which will likely affect the setts planted using conventional method. Whereas, for the late cropping season (L) as observed from figure 3, it was observed that there was sufficient moisture from both rainfall and AWA from 15th to 29th dekad which marked the period from planting to vegetative stage for the yam but inadequacy of moisture of about 6 dekads (between 8th -13th dekad). This period of short fall marked the planting date to early emergence stage. Other phonological stages enjoyed consistent of moisture supply except at the critical stage of moisture requirement of bulking, where excessive moisture was observed. The excessive moisture experienced during the late vegetative growth and tuber bulking period during the 2007 experimental year which could be attributed to part of high AWA which in particular during the period when P was consistently greater than PE. The high AWA experienced at this period could also cause leaching of plant nutrient which will reduce harvested tuber yield (Bello, 1997). It was observed that earlier planting so that the entire phenological stages coincided with period of AWA led to relatively longer period of complete plot emergence and the vegetative growth and consequently higher final yield is expected whereas, late planting led to a situation whereby the AWA was not able to satisfy the moisture requirement of crop at the critical moisture requirement period of bulking before the cessation of rains. Consequently both the tuber size and yam yield could be considerably lower, this agreed with Odjugo, 2008. Also Onwueme (1973) have indicated that moisture stress delay tuber initiation in yams. Generally, it was observed that for yam to survive the moisture stress experienced at the early periods of 2007 cropping season from the 1st to the 13th dekads, there is need for soil moisture conservation in the early season planting of yam, therefore, it is essential to apply mulching (IITA 1995). Furthermore, relating moisture based agro-climatic indices distribution to crop growth stages of white yam for 2008, It was observed that rainfall was sufficient for yam growth from end of 3rd dekad which marked the emergence period all through to harvesting for early planting, and from planting to harvesting for late planting. This showed that rainfall was well distributed during the 2008 growing season and a good yield is expected. However, observation also shows that sufficiency of rainfall does not imply availability of water to crop, it was observed that while rainfall distribution through the growing period consistently satisfied the water requirement of crop, the AWA distribution was less satisfactory particularly for the early planting season date. While rainfall started to satisfy the water requirement adequately from the 4th dekad, the AWA started by 16th dekad for the early planting. However, the AWA distribution was consistently satisfactory throughout the cropping season for the late planting. The better rainfall distribution as against the AWA distribution may be due to the fact that some of the rainfall may not find its way into the root zone of the crop but runoff into the streams, enters into the deep ground or loss to the atmosphere by evaporation. It is however important to stress the fact that the AWA from the figure 3 coincided with the water requirement at the 5th and 13th dekads which are the dekads for the emergence and vine elongation respectively. These showed that the AWA also satisfy the water requirement at the critical stages of water requirement of yam for the early season planting. However, it was observed that there was appreciable difference between AWA and water requirement during the late emergence and early vine elongation period for early planting.

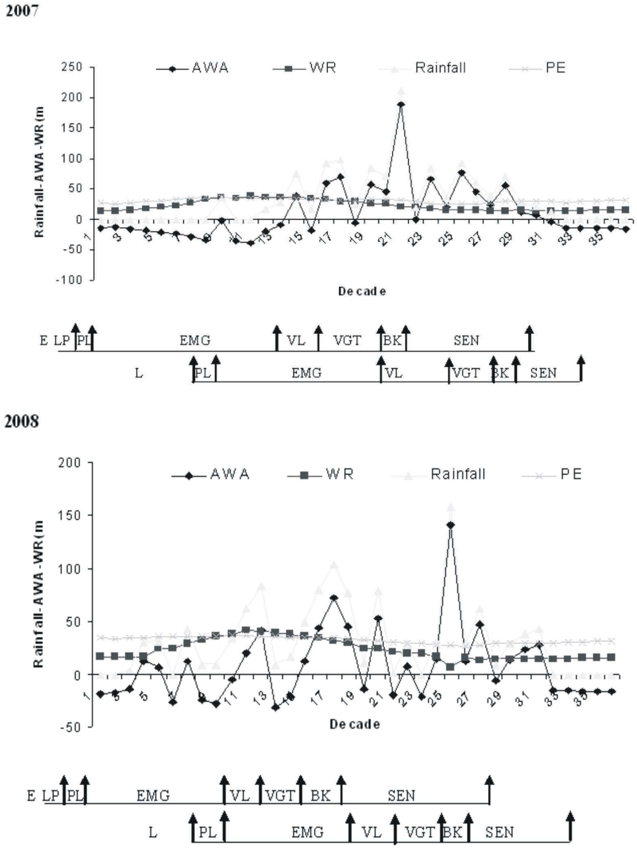


Fig. 3: Mean decadal rainfall, potential evapotranspiration (PE), actual water availability (AWA) and water requirement (WU) distribution different phenological stages of white yam

The lower AWA to the water requirement during these periods implied that PE was in excess of rainfall as observed in figure. When ever the PE was higher than rainfall, the AWA was observed to be low. However, because of the depletion in moisture in between the peaks of AWA at the 5th and 13th dekad, there is need for soil moisture conservation in the early season planting of yam, hence the importance of mulching (IITA 1995).

Distribution of water requirement satisfaction index (WRSI), actual water availability (AWA) and water requirement (WR) of white yam for 2007 and 2008 experimental years on decadal bases is as shown in Fig. 4.

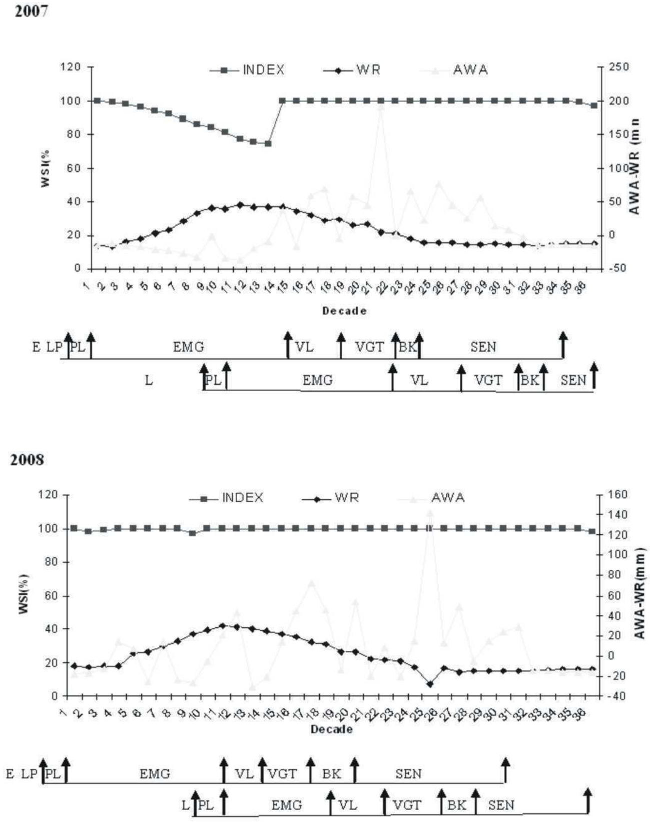


Fig. 4: Mean decadal water requirement satisfaction index (WRSI), actual water availability (AWA) and water requirement (WR) distribution at different phenological stages of white yam in Abeokuta

It was observed that the water requirement satisfaction index consistently declined throughout the emergence stage of yam planted during the early planting (E). Whereas, for the late planting (L) of 2007, the rainfall has adequately satisfied the water need of yam for the cropping season of the year except for the early emergence period that extended to the declining WRSI period of the year. These of cause will lead to a low yield as will be expected when the early season planting is adopted. Whereas, during the 2008 season as observed from Fig. 4, there was no marked difference in the water requirement satisfaction index for all the phenological stages of yam. The rainfall has adequately satisfied the water need of yam for the cropping season of the year.

Presented in Figure 5 is the limit of water adequacy for yam production following the method of Wolfgang (1981) by expressing effective water availability as the ratio between AWA and crop's water requirement (WR) for the 2007 and 2008 experimental years. It was evident that for the 2007 experimental year, the available moisture during the sensitive period of yam growth for the setts planted during the early stages (in particular during sprouting and emergence) of crop growth was grossly inadequate. However, for vegetative stage all through harvesting, there was adequate moisture supply for crop growth and furthermore, moisture was excessive during the critical stage of bulking. However, during the late planting season of 2007 experimental year from the AWA:WR ratio, the early stages of crop (period of planting to emergence) experienced moisture deficiency whereas during other stages of growth, moisture supply was adequate (effective water availability remained at the critical humidity level of above 2.0). Furthermore, excessive moisture supply was experienced at the later stages of growth from vine enlongation through bulking period. The extremely low values of AWA: WR ratio observed from planting to emergence period for early planting and early part of late planting season indicted that the AWA is highly deficient and there is possibility of yam sett rotting or getting burnt on mound since there is no moisture to compensate for water requirement of crop and this implied that the rainfall distribution during the periods was below the optimum required for the sprouting of yam seed. For 2008 cropping season however, the available moisture during the sensitive period was able to satisfy the optimum water requirement for yam production during the phonological stages of crop development.

Apart from the late growth stage 26-28 dekads when AWA:WR ratio indicated excess moisture supply for early planting date and bulking period inclusive for late planting, effective water availability remained at the optimal level (1.0-2.0) for the rest of the growing season. The low values of AWA: WR ratio observed from the emergence to vine elongation period at the early season planting indicted that the AWA effectively compensated WR. Generally, the early planting as in 2008 cropping season was observed to have more yield irrespective of yam variety when compared to early planting of 2007 cropping season as observed in Fig.6. Furthermore, the early planting 'E' was observed to have more yield than late planting "L" in both experimental years. The high yield from the early planting than the late planting for both experimental years can also be attributed to phosphorus and mineralized nitrogen which are naturally high during the early rains absorbed by yams during growth

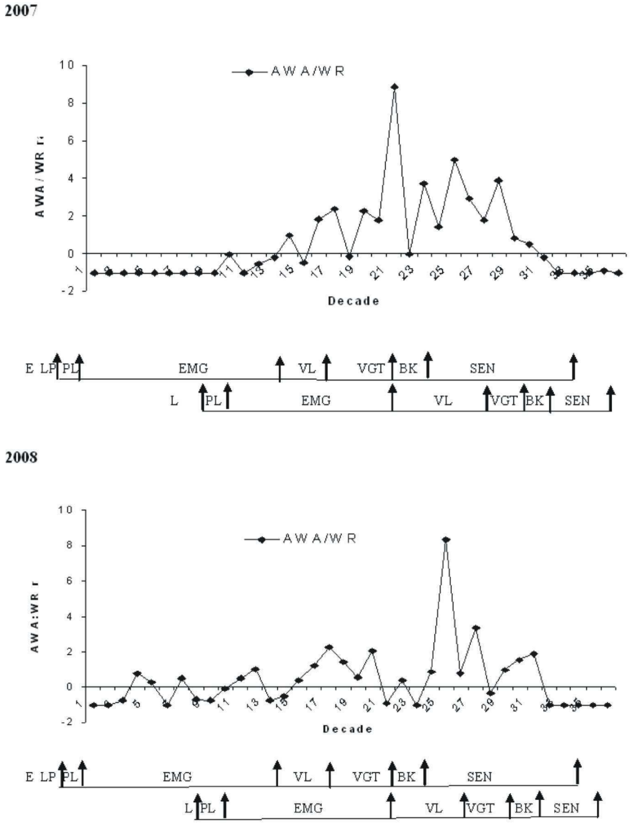
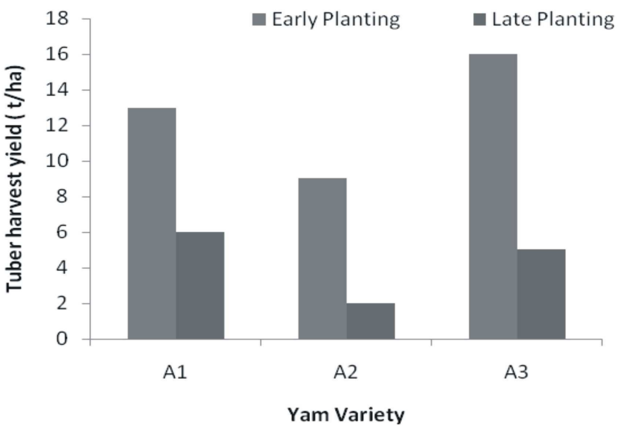


Fig. 5: Ratio between AWA and crop's water requirement (WR) at different phenological stages of white yam in Abeokuta

(Solubo, 1972 and Okigbo, 1980). The significant low yield arising from late planting implied that these natural nutrients were largely missed as they might have been lost to leaching. It is noteworthy that in the case of late onset of rains, farmers may become apprehensive of a planting period that fails to ensure that the crop matures by the end of the rains. Consequently, they may tend to adopt early planting in other to avoid possible incidence of drought at critical moisture period of bulking.

2007



2008

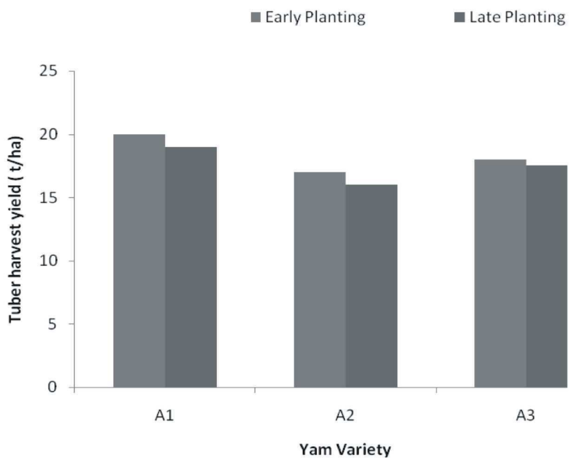


Fig. 6: Effect of planting season on tuber yield of three white-yam grown at Abeokuta

CONCLUSION AND RECOMMENDATIONS

From this study, it is obvious that knowledge of climatic conditions can allow us to develop a seasonal management strategy for yam production in Southwest Nigeria. The study revealed that partitioning of the growing season into different phenological stages for investigating crop will allow the determination of the extent to which the water availability will satisfy water requirement of crops during the different phenological stages. Such information helps in the design of appropriate technological/ agronomical devices that will maximize beneficial effects. For instance, a balanced water supply during critical water requirement such as active growth period of vine and leaf development, tuber initiation and bulking; the most critical stages being at tuber initiation and bulking will lead to an effective yield. On the other hand, too little or excess water supply is detrimental, as it might lead to poor development and growth of the crop and consequently low yield.

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