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An Assessment of Rain Water Supply for Kenaf- Maize Intercrop

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Abstract

Understanding the advantage of crop water use in mixed crops over sole cropping is vital in developing optimum water management crop production in the tropical wet-and-dry climate. This study investigated water supply potential for the cultivation of kenaf (Hibiscus cannabinus L.) – maize (Zea mays L.) intercrop in of South-western Nigeria. The phenological stages of each of the crops formed the basis for the investigation. The experiment comprises of two varieties of kenaf (Tainung 1 and Ifeken400), one variety of maize (DMR-LSR-Y) 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. Descriptive statistics was employed for the analysis. Relating the effective water availability to the indices of moisture adequacy for the growth of the crop in sole and intercrop, it was found that the agro-climatic moisture indices were optimum during the moisture sensitive stages particularly for early season planting irrespective of cropping pattern. A comparison of maize and kenaf production in sole or intercrop in the study area showed that early planting promotes the growth, development and yield irrespective of planting season. Mono-cropping maize and kenaf performed better than intercropping. However, water supply in rain-fed agriculture was confirmed to be efficient for maize/ kenaf intercrop in South-western Nigeria.

Keywords: Actual water availability; Crop's water consumption; Moisture indices; Intercrop

Introduction

Despite the tremendous improvements in technology and crop yield potential due to the attention recently given to the concept of agricultural sustainability, food production remains highly dependent on climate. Of all the climatic parameters involved in crop production, water supply is generally the most critical agro-meteorological factor limiting crop production where irrigation is not available [1,2], particularly in Africa where agricultural activities is largely rain fed. 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 which may last for a few days to more than three weeks. Incidence of wet season dry spells particularly during the full vegetative stage when evaporative demand is high can lead to retardation of yield formation [3]. However, for location with good soil moisture retention, the plants may manage to utilize soil moisture reserve contained in the pores of the soil, or upon the very limited reserve contained in its own tissue during dry spells between rains. Crop may also adapt physiologically or behaviorally to prevent temporary depletion of the stored tissue moisture in other to prevent impairment of normal physiological function that may cause irreversible damage and plant death. Olasantan [4] reported that majority of the traditional farmers in the tropics often practice intercropping system not only for their ecological stability, and bio-cultural sustainable attribute but also to reduce weed growth, maximum diurnal soil temperature and in particular evaporative water losses. By combining crops that have different growth pattern, the available land, soil, radiation, heat, water and nutrient can be better utilized in time and space as compared to sole cropping [5-7]. Many studies have shown that higher efficiencies can be achieved with intercropping in the utilization of radiation [8], nutrients [9], land [10,11] and water [12]. Intercropping fiber crop with legumes and cereals has been shown to give higher returns than sole cropping [13]. Thus, for sustainable agricultural production, researchers all over the world and in Nigeria in particular have not relented on their efforts at investigating both the positive and negative effects of intercropping.

Rainfall is the most important climatic factor that influences the pattern and productivity of rain fed maize in sub-Saharan Africa, since rainfall replenishes soil water used by crops [14-16]. A number of climatic factors such as low and erratic rainfall, constant low humidity levels and high temperatures during the growing season have influenced crop growth conditions [17]. Maize requires between 450 and 600 mm of rain per season, which is mainly acquired from the soil moisture reserves [18]. Maize production under rain fed conditions could be affected by the timeliness, adequacy and reliability of seasonal rainfall [19]. Ramadoss [20] found that rain fed maize production was severely impeded by water stress and high temperatures even if the soil water profile was full at the beginning of the growing season.

Kenaf cultivation and production is said to be suitable for the agronomic conditions in Nigeria [21] and it is gradually gaining relevance in the intercropping system in some part of the country because of its economic potential and role in the cottage fiber industry [22]. The crop prefers area of rainfall of 500-600 mm over 4-5 months with wet and dry periods. Kenaf may be useful in alleviating global warming not only because of its absorbing potential for carbon dioxide gases due to its rapid growth rate but also its absorption rate is five time that of forest [23]. The usual time for planting kenaf in Nigeria

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coincides with that of maize, cowpea, sorghum, groundnut among others [24]. Research into kenaf with other food crop has been extensive in Nigeria [25-29]. However the assessment of water supply for the kenaf in intercrop is rare. This study was undertaken to assess rain water supply in kenaf - maize mixtures.

Materials and Methods

Description of study area

The research was conducted at the Teaching and Research farm of Federal University of Agriculture along Alabata road, Abeokuta (7º 15'N, 3º25'E) in Odeda Local Government Area of Ogun State, South Western Nigeria (Figure 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 30ºC. 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 [4].

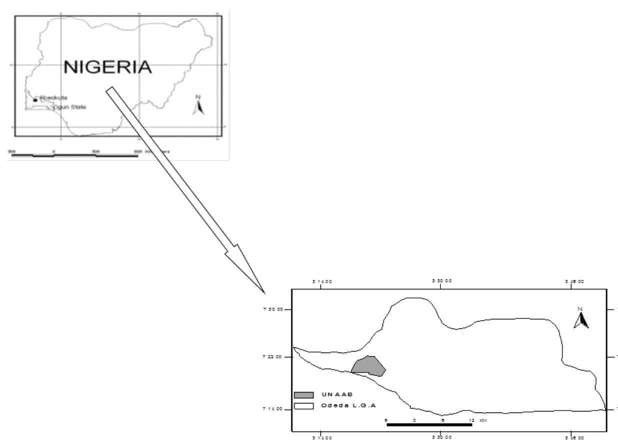

Figure 1: Location of University of Agriculture, Abeokuta within Odeda Local Government Area in Ogun State, Southwestern Nigeria.

Experimental design and field measurement

The experimental site comprised of 30x12m^2 land which had previously carried beans (Vigna sinensis) and groundnut (Arachis hypogaea) intercrop but had been fallowed for over 6 years. The site was cleared manually using cutlass and plantings were carried out during the late May and early August for early and late cropping seasons respectively. Four seeds of kenaf cuiltivars (Tainung 1 and Ifeken 400) and maize cultivar (DMR-LSR-Y) were sown per hole in their respective plots at depth of 2.5 cm. At 2 decade after sowing (DAS), kenaf and maize seedling were thinned to two and one plant(s) per stand respectively. The iner and intra row spacing in kenaf was 1x0.5 m resulted in a population of 40,000 ha^{-1}, while maize was 1x1 m resulted in a population of 10,000 ha^{-1}. The sole kenaf and maize spacing were 0.5x0.2 m and 0.75x0.25 m resulting in a plant population of 100,000 ha^{-1} and 53,000 ha^{-1}respectively. All plots were treated with a post- emergence application of N.P.K 15: 15: 15 fertilizer at the rate of 120 Kg ha^{-1}. A mixture of Punch and Karate herbicides was applied at the rate of 4 ml/l on equal basis and all plots were regularly weeded using traditional hoe. In other to relate the moisture indices of the study area to the climatic requirements of kenaf- maize intercop from planting to harvesting, the moisture base agro-climatological indices for the crop growth were measured according to phenological stages of the crops. In this study, four developmental stages of kenaf and maize growth cycles form the time-scale for which the collected data have been processed, this includes establishment, vegetative (stem girth and plant height), flowering and fruiting for kenaf and establishment, vegetative (stem girth, plant height and tesseling), silking and grain filling for maize. During each of the rephonological stages, daily observation of air temperature (ºC), 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 formula according to FAO [1], actual water availability (AWA, mm) and consumptive water used by the crop (ET_{crop}) in mm is determined as follow:

$ET_{crop} = K_{CO}$ x E_O 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, (K_{co}) 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 [1] for tuber crops. Actual Water Availability (AWA in mm) is taken as the difference between actual precipitation and crop water requirement,

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

AWA 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. Deichmann and Eklundh [30] set an aridity limit at 1.0 and a critical humidity limit at 2.0. Therefore the moisture supply for maize and kenaf 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 [31].

Results and Discussion

Dekadal rainfall potential evapotranspiration distribution for 2007 and 2008 cropping seasons were related to the phenological growth and development stages of kenaf and maize for both early and late seasons in Figures 2-4. The humid period was observed for most parts of early cropping seasons (Figures 2 and 4) with dry spell of between 1 to 2 decades during the early vegetative stage of both maize and kenaf (between 3 to 5DAP) and at 8 and 10 DAP which marked the beginning of flowering and fruiting period respectively for kenaf and early fruiting for maize (Figure 2). Longer dry spell of 4 decades (between 7 to 10 DAP) was experienced in early cropping of 2008 trail (Figure 4) which coincides with late vegetative and flowering period

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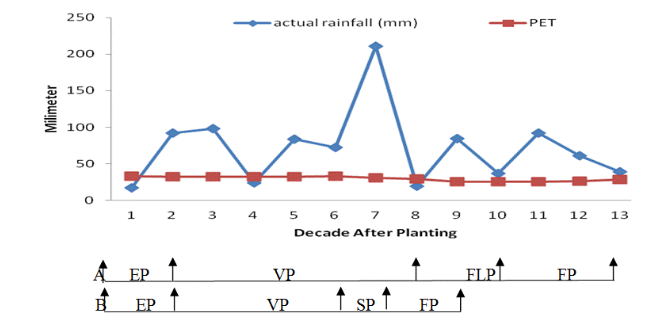
for kenaf and silking and fruiting period for maize. Furthermore, the early stages of growth (establishment and most part of vegetative) falls in the humid periods for late cropping in 2007and 2008 trails (first 7 DAP), while the remaining 6 DAP (7 to 13 DAP) where dry period with PET > P which marks the flowing and fruiting for kenaf and silking and fruiting for maize in both trails (Figures 3 and 5).



EP = Establishment period, VP = Vegetative period, FLP = Flowering period FP = Fruiting period, SP = Silking period

A = Sole Tainung 1, B = Sole Ifeken 400, C = Tainung/Maize, D = Ifeken 400/Maize, E = Sole Maize

Figure 2: Mean decadal rainfall-potential evapotranspiration relationship at different phenological stages of kenaf and maize in early cropping season of 2007

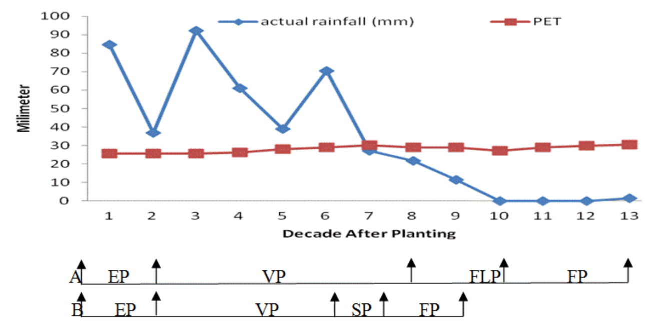


Figure 3: Mean decadal rainfall-potential evapotranspiration relationship at different phenological stages of kenaf and maize in late cropping season of 2007

An investigation into the moisture adequacy for kenaf-maize intercrop for 2007 and 2008 trails in Figures 6- 9 shows that moisture was adequate for both maize and kenaf irrespective of cropping system for early planting season (Figures 6 and 8). However, inadequate during the 4, 8 and 10 DAP for 2007 trail and grossly inadequate between 5 and 10 DAP during the 2008 trail. The bad hit was the kenaf/ maize intercrop followed by sole maize. The long term moisture stress of 2008 as a result of short fall in rainfall during late vegetative and flowering period for kenaf and fruiting period for maize is expected to lead to growth retardation and reduction in yield particularly for farmers in the area that depended solely on rainfall for planting. However, during this long moisture stress period, the down pour of the 11 decade was able to replenish the deficiency at the root zone of the crops as a result of infiltration into pore spaces in the soil which could prevent total for the early season planting.

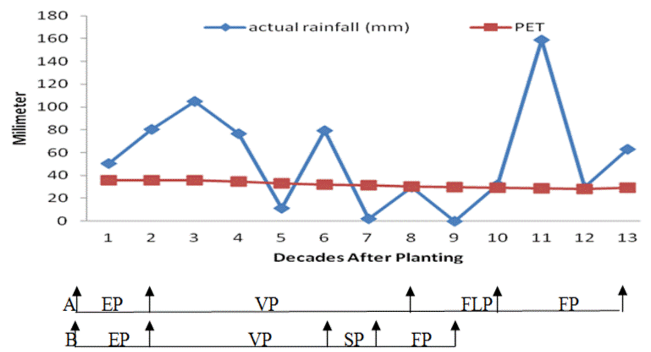


Figure 4: Mean decadal rainfall-potential evapotranspiration relationship at different phenological stages of kenaf and maize in early cropping season of 2008

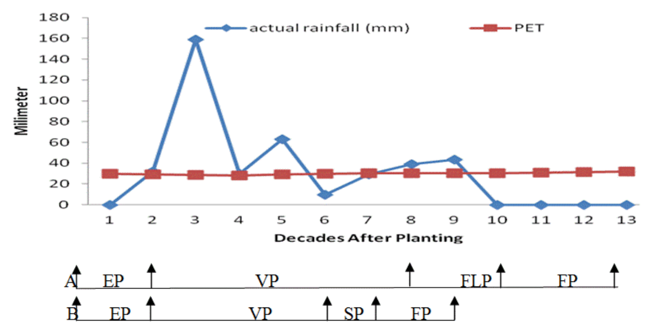


Figure 5: Mean decadal rainfall-potential evapotranspiration relationship at different phenological stages of kenaf and maize in late cropping season of 2008

Whereas, for the late cropping season as observed from Figure 7 and 9, there was sufficient moisture from AWA for the first 6- 7 decades in both 2007 and 2008 trails which marked the period from establishment to early vegetative stage for both kenaf and maize but inadequacy of moisture of about 6 decades (between 8 -13 DAP) were experienced. This period marked the end of vegetative to fruiting in kenaf and silking and fruiting for maize. The kenaf/ maize intercrop and sole kanaf suffers mostly because of the length of growing period for kanaf which is higher than that of maize. Generally, 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 establishment 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 crops at the critical moisture requirement period of silking and fruiting before the cessation of rains. Consequently both the seed yield and fibre yield for kenaf and the ear weight and grain yield for maize could be considerably lower, this agreed with Katuung [24]. Also Sullivan [32] have indicated that prolong moisture stress during the vegetative period could inhibit vegetative growth. Generally, it was observed that sole cropping system in kenaf and maize enjoys more moisture availability than when in kenaf / maize intercrop, although, there was

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little difference in most cases. The results are similar to those by several researchers [33,34].

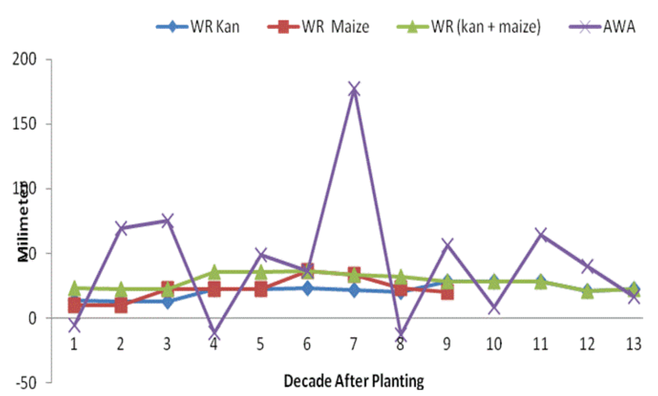

Figure 6: Actual water availability (AWA) and water requirement (WU) distribution of kenaf/maize intercrop in early cropping season of 2007

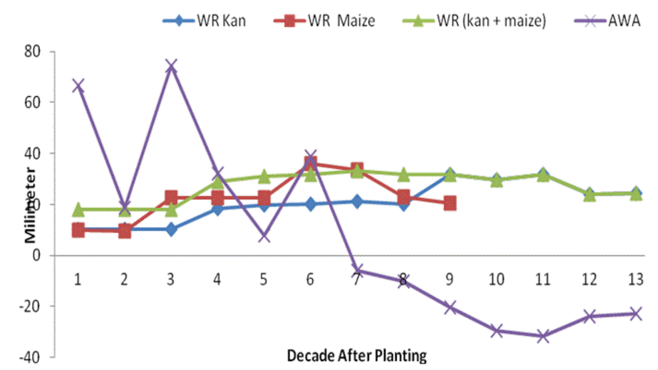

Figure 7: Actual water availability (AWA) and water requirement (WU) distribution of kenaf/maize intercrop in late cropping season of 2007

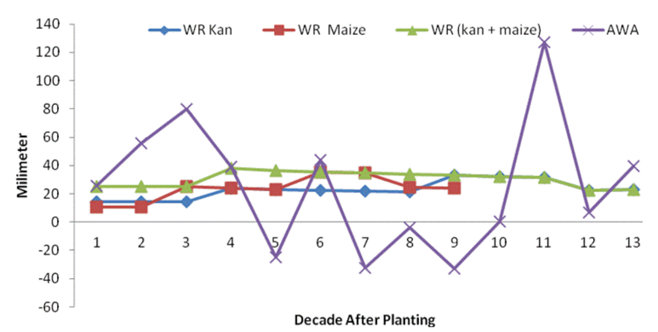

Figure 8: Actual water availability (AWA) and water requirement (WU) distribution of kenaf/maize intercrop in early cropping season of 2008

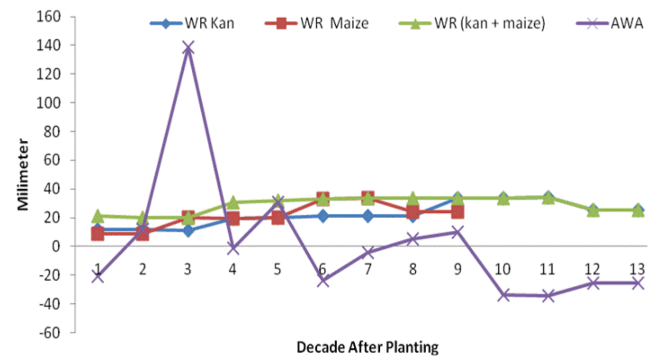

Figure 9: Actual water availability (AWA) and water requirement (WU) distribution of kenaf/maize intercrop in late cropping season of 2008

Presented in Figures 10 to 13 is the limit of water adequacy for kenaf/ maize intercrop following the method of Deichmann and Eklundh [30] 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 the available moisture during sole kenaf and maize during the early planting was more adequate than when intercropped in particular for 2007 cropping season. However, gross inadequacy of moisture was experienced during the dry spells between 6 and 10 DAP (late vegetative to flowering period for kenaf and silking and fruiting for maize) in 2008 trails for both sole and intercrop (Figures 10 and 12). However, during the late planting for 2007 and 2008 trials, moisture was inadequate from 7DAP upward. This extremely low values of AWA: WR ratio observed from late vegetative, flowering and fruiting periods for kenaf and from silking to fruiting in maize indicted that the AWA is highly deficient during these stages and there is possibility of low yield since there is no moisture to compensate for water requirement of crops and this implied that the rainfall distribution during the periods was below the optimum required for these stages of growth for both sole and intercropping of both kenaf and maize. Most badly hit was the intercropped kenaf/ maize.

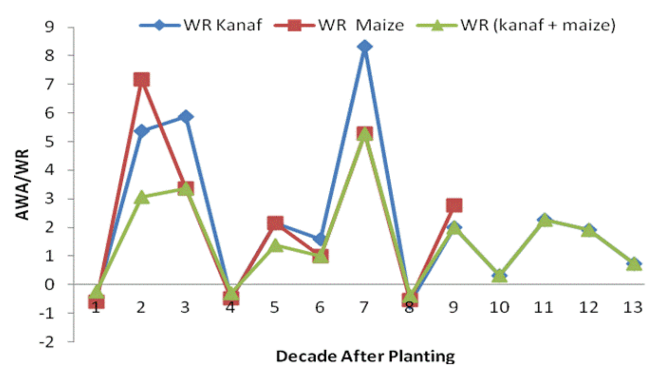

Figure 10: Ratio between AWA and crop's water requirement (WR) at different phenological stages of kenaf/maize intercrop in early cropping season of 2007

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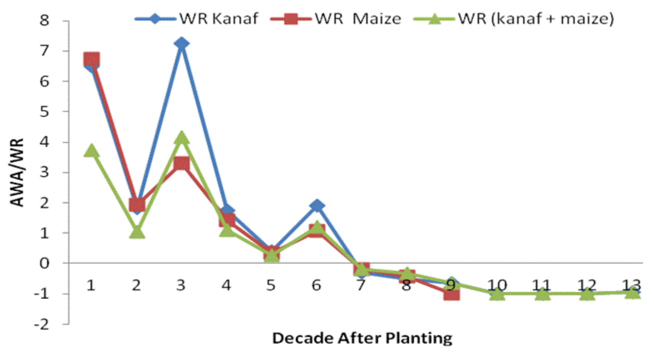

Figure 11: Ratio between AWA and crop's water requirement (WR) at different phenological stages of kenaf/maize intercrop in late cropping season of 2007

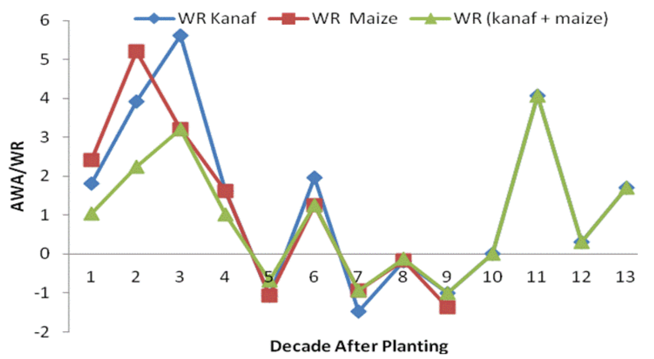

Figure 12: Ratio between AWA and crop's water requirement (WR) at different phenological stages of kenaf/maize intercrop in early cropping season of 2008

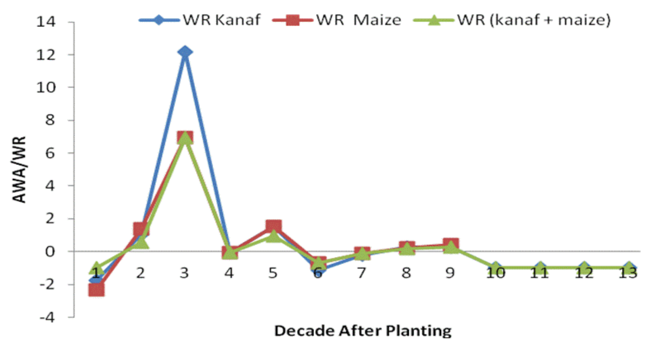

Figure 13: Ratio between AWA and crop's water requirement (WR) at different phenological stages of kenaf/maize intercrop in late cropping season of 2008

Generally, the early planting as in 2007 and 2008 cropping season (Figures 14-17) was observed to have more ear weight and grain yield for maize and seed yield and fiber yield for kenaf than late planting season. The grain yield of maize in early planting season (3.68 t/ha and 3.24 t/ha for 2007 and 2008 respectively) was higher than the late planting season (2.85 t/ha and 2.53 t/ha for 2007 and 2008 respectively) as shown in Figures 14 and 16. However, the kenaf planted during the early planting season produced higher bast fibre (2.84 t/ha and 2.45 t/ha for 2007 and 2008 respectively) than the kenaf sown in late planting season (1.74 t/ha and 1.30 t/ha for 2007 and 2008 respectively). The higher best fiber in kenaf during the early than late season may be as a result of longer vegetative stages which resulted to taller plant height during the early planting season. The high yield recorded during the early planting for both experimental seasons could also be attributed to phosphorus and mineralized nitrogen which is naturally high during the early rains absorbed by both kenaf and maize during growth [35,36]. The significant low yields 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 for the first moisture period (August break). Consequently, they may tend to adopt early planting in other to avoid possible incidence of drought at critical moisture period of flowering and fruiting for kenaf and silking and fruiting for maize. However, seed yield was higher in late planting season (1.70 t/ha and 0.70 t/ha for 2007 and 2008 respectively) than the early planting season (1.45 t/ha and 0.65 t/ha for 2007 and 2008 respectively) as shown in Figures 15 and 17. This agreed with Adeniyan [26].

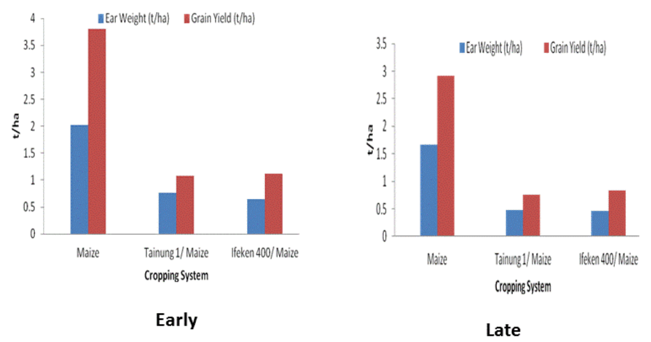

Figure 14: Yield of maize in kenaf/maize intercrop in early and late cropping season of 2007

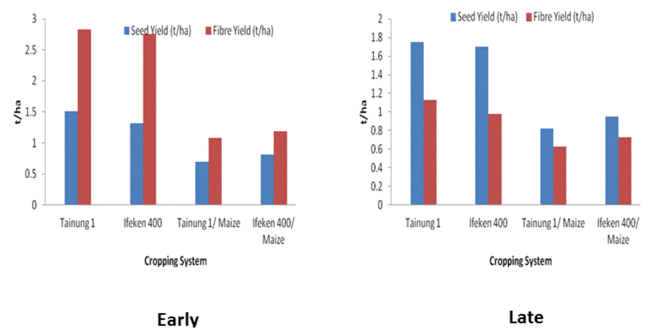

Figure 15: Yield of kenaf in kenaf/maize intercrop in early and late cropping season of 2007

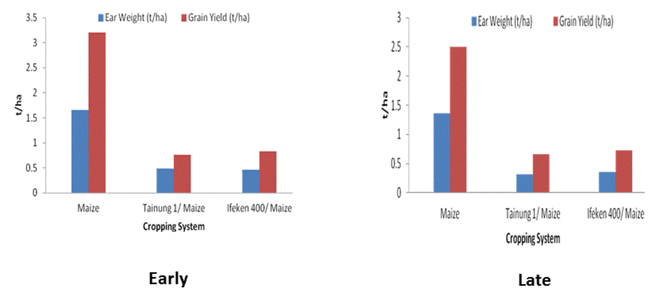

Figure 16: Yield of maize in kenaf/maize intercrop in early and late cropping season of 2008

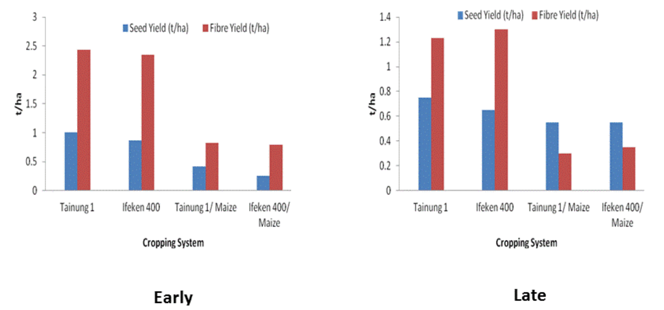

Figure 17: Yield of kenaf in kenaf/maize intercrop in early and late cropping season of 2008

Investigation into the effect of intercropping on the yield shows that irrespective planting season, sole cropping system performed better than intercropping in the yield of maize and kenaf in kenaf/ maize intercrop. The yield of maize in kenaf/ maize intercrop during the early and late planting season in Figures 14 and 16 showed that during the early planting season, sole maize had the highest grain yield of 3.80 t/h and 3.25 t/ha for 2007 and 2008 respectively, while maize in Ifeken 400/ maize and Tainung 1 / maize had grain yield of 0.85 and 0.80 t/ha respectively for 2007 and grain yield of 0.75 and 0.70 t/ha respectively for 2008. Similarly, the result revealed that during the late planting season, sole maize produced highest grain yield (2.82 t/ha and 2.45 t/ha for 2007 and 2008 respectively), while maize in Ifeken 400/ maize produced grain yield of 0.75 t/ha and 0.65 t/ha for 2007 and 2008 respectively and maize in Tainung 1 / maize produced grain yield of 0.65 t/ha and 0.60 t/ha for 2007 and 2008 respectively. Furthermore, the yield of kenaf in kenaf/ maize intercrop during the early and late planting season in Figures 15 and 17 revealed that monoculture cropping system during the early planting season revealed that the yield components of Tainung 1(1.50 t/ha and 2.73 t/ha for seed and fibre respectively in 2007 and 1.0 t/ha and 2.40 t/ha for seed and fibre respectively in 2008) was higher than Ifeken 400 (1.25 t/ha and 2.75 t/ha for seed and fibre respectively in 2007 and 0.75 t/ha and 2.35 t/ha for seed and fibre respectively in 2008), while in mixed cropping system, the reverse was the case. Late planting season showed Ifeken 400 had higher seed yield (1.70 t/ha and 0.75 t/ha for 2007 and 2008 respectively) than Tainung 1 (1.75 t/ha and 1.60t/ha for 2007 and 2008 respectively), while for fibre yield of Ifeken 400 (0.90 t/ha and 1.30 t/ha for 2007 and 2008 respectively) was lower than Tainung 1 (1.10 t/ha and 1.25t/ha for 2007 and 2008 respectively). There were no distinct differences in Tainung 1 in Tainung1/ maize intercrop produced 0.65 and 0.85 t/ha of seed and fibre yield in 2007 and 0.40 and 0.80 t/ha of seed and fibre yield in 2008. The higher yield in monoculturre cropping system than intercropping could be attributed to competition for water by the co-existing species in the mixture, thus reducing the yield of less competitive component. Such result was reported by Ogindo and Walker [34].

Conclusion and Recommendations

From this study, it is obvious that knowledge of climatic conditions can allow us to develop a seasonal water management strategy for intercropping of crops 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 irrespective of cropping pattern. 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 flowering and fruiting in kenaf and silking and fruiting in maize irrespective of cropping pattern 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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