



PHENOLOGICAL WATER BALANCE APPROACH FOR THE DETERMINATION OF OPTIMUM SOWING DATES FOR MAYA MAIZE (*ZEAMAYS*) IN A FOREST-SAVANNA TRANSITION ZONE OF NIGERIA

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ABSTRACT

The study determined the preparatory period, rain onset, and the sowing period limit, it also assessed the planting dates in relation to growth parameters and evaluated the effects of the planting date on grain yield of Egun maize. This research used an agroclimatological water balance method based on rainfall and potential evapotranspiration ($P - PE$) model to find the best time to plant Maya maize (*Zea mays*) in Abeokuta. Three planting dates derived from the ($P - PE$) model were used: D1 (April 27) when the accumulated difference between rainfall and half potential evapotranspiration was zero ($\Sigma P - 0.5PE = 0$); D2 (May 4) when $\Sigma P - 0.5PE = 6\text{mm}$; and D3 (May 11) when $\Sigma P - 0.5PE = 10\text{mm}$. The Maya maize was planted in a randomized complete block design with three replicates. Data collected were subjected to analysis of variance (ANOVA) and means were separated using LSD. Result showed that the optimum planting dates of Maya maize was April 27, with yield of about 3229.17 kg/ha. Planting dates had no significant effects ($p > 0.05$) on the growth parameters of Maya maize. The schedule of farm operations for maize cultivation showed that, land preparation should commence as soon as the accumulated difference between P and $0.5PE$ approaches zero while ridging and planting could be done simultaneously. The variability of rainfall is not limited to extreme condition of wetness due to prolonged wet spells and loss of soil nutrients might increase with higher accumulated difference between P and $0.5PE$, this implies that early planting of Egun maize is encouraged to improve yield due to higher nutrients availability at the early dates of sowing. The study concluded, that planting Maya maize around April 27 optimizes grain yield by ensuring better nutrient availability and reducing the risk of nutrient loss due to prolonged wet spells.

Keywords: Maya, Maize, Phenology, Water, Sowing, Date

INTRODUCTION

Based on interaction among the farmers in Abeokuta, Southwest Nigeria, it has been observed that determining the precise commencement of the rainy season poses a significant challenge. This uncertainty often led to the incorrect scheduling of agricultural activities, resulting in the failure of annual crops and repeated replanting attempts until reliable rainfall is established, (Fayose and Fakorede, 2021). Consequently, maize, which is one of first annual crops sown at the start of the rains, suffers from low yields, threatening both food security and livestock feed availability in Nigeria. (Adesina *et al.*, 2020). Quantitative data indicates that unpredictable rainfall patterns have resulted in an average yield loss of maize annually over the past decades. Agroclimatological water balance which is based on the relationship between rainfall and potential evapotranspiration, is a crucial method in understanding the reliable availability of water in the soil component of the plant environment, especially in the context of a changing climate. This approach is vital for determining the start of the growing season, which directly influences the optimal planting date, particularly for rain-fed agriculture. Ensuring food security, especially the assurances of food production and availability in an era of climate change, necessitates ongoing investigation of plant-climate relationships over space and time. Such investigations involve analysing the thermal, moisture and aerodynamic agroclimatological indices and their interaction with terrestrial agro-



ecological systems, particularly plants and animals. In the tropics, moisture based agroclimatological indices, such as rainfall, are particularly critical due to their limited availability compared to thermal (e.g., solar radiation) and aerodynamic (e.g., wind) factors. According to Bello *et al* (2010) a balanced water input is more beneficial to plants than either a surplus or deficit of water. This study aims to apply an agroclimatological water balance to determine optimum planting date for Maya maize in Southwest Nigeria.

MATERIALS AND METHODS

Study Area

The study was conducted in the Alabata section of Odeda Local Government Area, located in the northeast part of Abeokuta. The region falls within the sub-humid climate zone of southwest Nigeria.

EXPERIMENTAL SITE AND LOCATION

The experiment was hosted at the Federal University of Agriculture, Abeokuta (FUNAAB) Teaching and Research Farm Land from April to July of 2022, coinciding with the first part of the wet season. The location is situated at an elevation of 141 meters above mean sea level, between latitudes 7°20' and 7°32' N, and longitudes 3°35' and 3°47'. The soil at the experimental site is classified as a well-drained tropical ferruginous soil. The A horizon of the soil is an Oxic Paleudulf of the Iwo series characterized by 83% sand, 5% silt and 12 % clay with a pH of 6. These properties are consistent with the morphological and physical characteristics of selected maize growing soils in Nigeria described by Asadu *et al.*, 2015 and Olsantan, 2007. According to Winfred *et al* (2017), the soil can be classified as Ferric Luvisol soil due to its sandy clay texture with high organic matter content. The research region experiences a tropical climate with well distinct wet and dry seasons. The bimodal rainfall pattern of FUNAAB, begins March, with peaks in July and September, and a brief dry spell in August. The dry season extends from November to February. The area receives annual rainfall between 1100 and 1500 mm and has a relatively high average temperature of 27 °C. Relative humidity reaches its lowest levels, (78-90%) during the peak of the rainy season between June and September. According to Thornthwaite's (1948) climate classification methodologies, the research region is categorized under the sub-humid climate of southwest Nigeria.

LAND PREPARATION AND LAYOUT OF EXPERIMENTAL PLOTS

The experimental site, measuring 32 m × 16 m, was cleared and prepared manually using hoe and cutlass in early April 2022. The land has been under natural fallow for one year before the study commences. Ridges were constructed to prevent erosion and to ensure soil uniformity. The experiment plots were arranged in a 3 by 3 design within a randomized complete block design (RCBD). The experiment involved three different planting dates replicated three times, with each plot covering 12m².

DATA COLLECTION AGROMETEOROLOGICAL DATA

Air temperature (T, °C), open surface water evaporation (E_o, mm), and rainfall (P, mm), were recorded at an agrometeorological station in FUNAAB's enclosure near the experimental field throughout each phenological phase, Relative humidity (Rh, mm) and Sunshine hour (hr) were also measured.

CROP GROWTH AND YIELD PARAMETERS

Crop Growth Parameters: Parameters measured included plant height (cm), stem girth (cm), leaf area, number of leaves, days to 50% emergence (EMG), days to silking (SLK), and days to physiological maturity (PM).

Yield Parameters: Parameters such grain yield, cob weight, length and diameter of cobs were measured at maturity.

DETERMINATION OF PREPARATORY, START AND LIMIT OF SOWING PERIOD

THE PREPARATORY, START AND THE LIMIT OF THE SOWING PERIODS WERE DETERMINED USING RAINFALL-POTENTIAL EVAPOTRANSPIRATION (P-PE) MODEL AS THEORETICALLY ILLUSTRATED IN FIG 1.

According to the model:

- The start of sowing (Onset) of the rains is determined when accumulated difference between rainfall and half potential evapotranspiration is equal to or greater than zero, provided that a dry spell of five days or more did not occur in the week following and preceding the date of onset. This is expressed as: $\sum(P-0.5PE) \geq 0$
- Pre-sowing period (Preparatory Period) is determine when accumulated difference between rainfall and one-tenth of potential evapotranspiration is equal to or greater than zero. This is expressed as:
 $\sum(P-0.1PE) \geq 0$
- The limit of sowing period (Intermediate period) is determined when accumulated rainfall is greater than half of potential evapotranspiration which in turn is less than potential evapotranspiration. This is expressed as: $\sum(P > 0.5PE < PE)$.

ASSESSMENT AND EVALUATION OF PLANTING DATE IN RELATION TO GROWTH AND YIELD PARAMETERS OF MAYA MAIZE

The Maya maize was planted at interval of 7 days, with first planting date done on April 27th, the second on May 4th and third on May 11th.

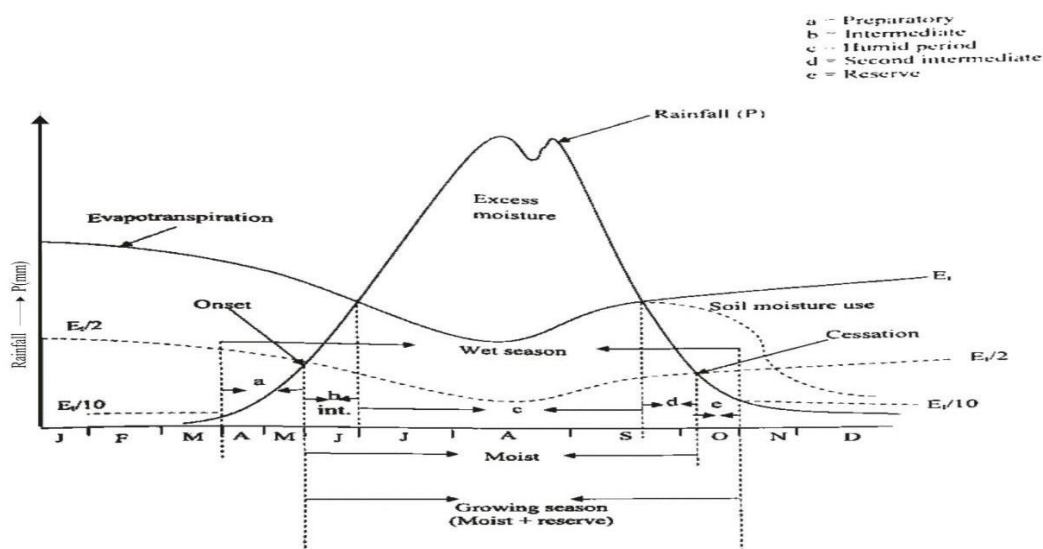


Figure 1: Rainfall – Potential Evapotranspiration Relation Model Bello (2000)

DATA ANALYSIS

Data collected were subjected to analysis of variance (ANOVA) to determine the effect of planting dates on the performance of maize cultivar during the phenological stages. Differences among means were compared using Least Significant Difference (LSD) at a 95% confidence level.

RESULTS AND DISCUSSION

MODEL RESULTS FOR PRE-SOWING, SOWING TIMING AND FARM OPERATIONS

The outcome of the model for determining pre-sowing, start, and limit of sowing, as well as farm operations during the experimental period from January to September 2022 in Abeokuta, is presented in Figure 2 and Table 1. The first planting occurred when accumulated difference between rainfall and half the potential evapotranspiration (PE) recorded from January reached zero ($\sum(P-0.5PE) \geq 0$). Planting ceased when this accumulated difference became negative ($\sum(P-0.5PE) \leq 0$). Farm operations were scheduled within the time period defined by $0.5PE \geq P \leq PE$. Planting was conducted at 7-day intervals, beginning on April 27th (D1) with accumulated difference of $\sum(P-0.5PE) = 0$ mm, followed by May 4th (D2) with $\sum(P-0.5PE) = 6$ mm and May 11th (D3) with $\sum(P-0.5PE) = 10$ mm. According to the P-PE model, the timeframes for land preparation and planting

spanned March 24th to April 27th, while planting period extended from April 27th to May 25th in the study area. This agreed with Sobowale *et al* (2016) that the onset and cessation dates varied across the locations that were considered; Ibadan, Abeokuta and Ondo had an early onset of rain while Ondo and Oshogbo had a late cessation of rain.

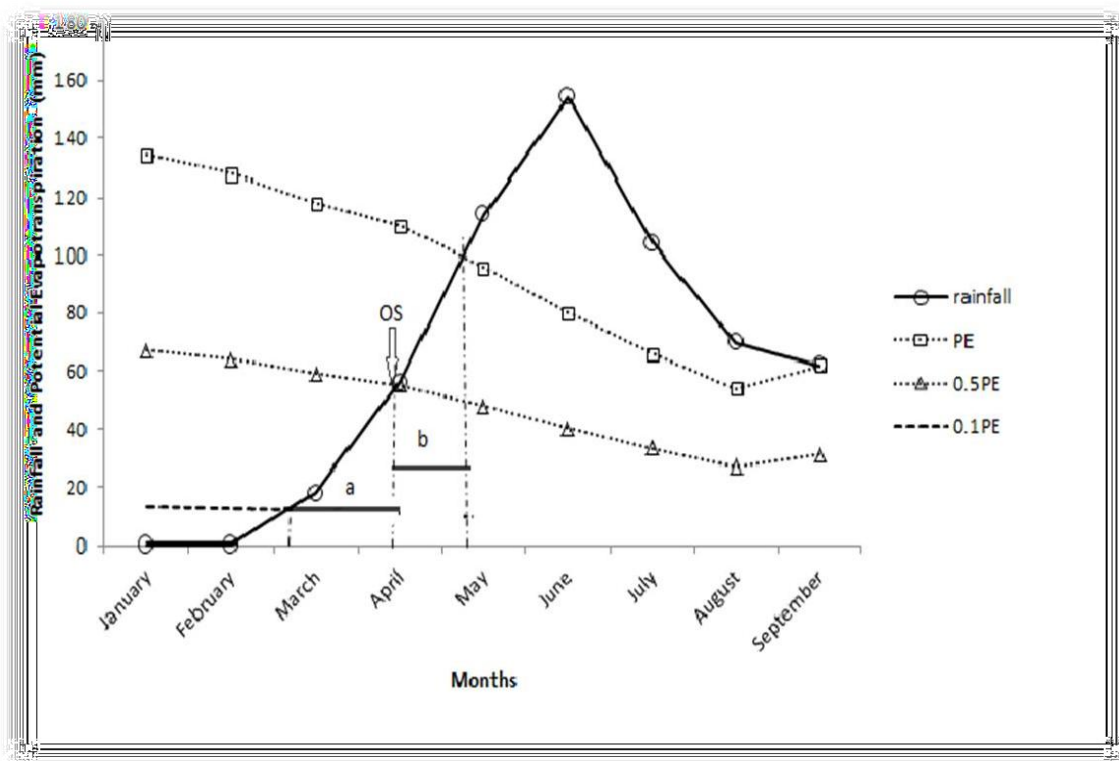


Figure 2: Rainfall-Potential Evapotranspiration Relations during January to September 2022 Planting Season in Abeokuta

Table 1: Model Results for Pre-sowing, Sowing Timing and Farm

Operations	Model description/Farm operations	Time Interval (Dates)	
	Duration (Days)	Preparatory	
period: $\sum(0.1PE < P < 0.5PE)$	March 23 – April 27		35
Limit period: $\sum(0.5PE < P < PE)$	April 27 – May 25		29
Planting D1/Onset: $\sum(P - 0.5PE) = 0$ mm	April 27		-
Planting D2: $\sum(P - 0.5PE) = 6$ mm	May 4		-
Planting D3: $\sum(P - 0.5PE) = 10$ mm	May 11		-

PHENOLOGICAL STAGE DURATION AND GRAIN YIELD AT DIFFERENT PLANTING DATES

Table 2 summarizes the observed duration of each phenological stage and grain yield for Maya maize during the growing period. For days to emergence, Maya maize planted during second and third planting dates (D2 and D3) took longest time to emerged with 6 days while Maya maize planted at first planting date (D1) recorded the lowest emergence of 5 days. Regarding days to tasseling, Maya maize planted during third planting date (D3) had the highest tasseling of 55 days, followed by those planted at the second planting date (D2) with 53 days while Maya maize planted at first planting date (D1) recorded the lowest tasseling of 51 days. For days to silking, Maya maize planted during third planting date (D3) had the highest silking of 59 days followed by those planted at the second planting date (D2) with 57 days while Maya maize planted at first planting date (D1) recorded the lowest silking of 56 days. Regarding days to physiological maturity, Maya maize planted during third

planting date (D3) had the highest physiological maturity of 85 days followed by those planted at the second planting date (D2) with 83 days while Maya maize planted at first planting date (D1) recorded the lowest physiological maturity of 81 days. In term of grain yield, Maya maize planted during first planting date (D1) had the highest grain yield of 3958.33 kg/ha followed by those planted at the second planting date (D2) with 2059.50 kg/ha while Maya maize planted at third planting date (D3) recorded the lowest grain yield of 1666.67kg/ha.

Table 2: Phenological Stage Duration and Grain Yield of Maya Maize (V2)

Planting date	Days to Emergency	Days to Tasseling	Days to Silking	Days to Physiological maturity	Grains yield (kg/ha)
D1(April 27)	5	51	56	81	3958.33
D2(May 4)	6	53	57	83	2059.50
D3(May 11)	6	55	59	85	1666.67
LSD (0.05)	0.811	0.72	1.93	2.09	912.96

GRAIN YIELD AND YIELD CHARACTERISTICS OF MAYA MAIZE AT DIFFERENT PLANTING DATES

Table 3 is the response of grain yield and yield characteristics of Maya maize to planting date in Abeokuta. There was significant different ($p < 0.05$) across the maize yield and yield characteristics of Maya maize. Maya maize planted during first planting date (D1) had the highest cob diameter of 3.63 cm, followed by those planted at the second planting date (D2) with 2.63 cm while Maya maize planted at third planting date (D3) recorded the lowest cob diameter of 2.40 cm. Similarly, Maya maize planted during first planting date (D1) had the highest cob length of 21.80 cm, followed by those planted at the second planting date (D2) with 16.60 cm, while Maya maize planted at third planting date (D3) recorded the lowest cob length of 16.17 cm. Additionally, Maya maize planted during first planting date (D1) had the highest weight of fresh grain yield per cob of 119.33 g followed by those planted at the second planting date (D2) with 83.67 g while Maya maize planted at third planting date (D3) recorded the lowest weight of fresh grain yield per cob of 55.33 g. Maya maize planted during first planting date (D1) had the highest grain yield of 3958.33 kg/ha, followed by those planted at the second planting date (D2) with 2059.50 kg/ha while Maya maize planted at third planting date (D3) recorded the lowest yield of 1666.67 kg/ha.

TABLE 3: EFFECTS OF PLANTING DATE ON GRAIN YIELD AND YIELD CHARACTERISTICS OF MAYA MAIZE IN ABEOKUTA

Planting date	Cob (cm)	diameter (cm)	Cob (cm)	length (cm)	Wt.of grain/cob (g)	fresh	GrainYield (kg/ha)
D1(April27)	3.63		21.80		119.33		3958.33
D2(May 4)	2.63		16.60		83.67		2059.50
D3(May 11)	2.40		16.17		55.33		1666.67
LSD(0.05)	0.98		3.95		31.82		904.12

CONCLUSION AND RECOMMENDATION

It can be inferred from the findings, that farmers can use this information to optimize their planting schedules for higher yields as the findings underscore the importance of proper management practices, including timely planting, to achieve maximum Maya maize yield potential. Overall, the findings provide valuable insights for farmers and agricultural practitioners in Abeokuta and similar agroecological zones on how planting dates can influence maize yield and characteristics, aiding in better decision-making for improved agricultural productivity in view of prevailing unpredictable



climate vagaries which can lead to reduction in the final yield when planting was done at the wrong period.

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