ISSN 2349-7823

International Journal of Recent Research in Life Sciences (IJRRLS)
Vol. 9, Issue 2, pp: (71-78), Month: April - June 2022, Available at: www.paperpublications.org

Response of some morphological characteristics of maize (*Zea mays* L.) to environment, season and weather factors in a tropical rainforest location

[1]C. A. FAYOSE, [2]M. A. B. FAKOREDE, [3]A. OLUWARANTI

Department of Crop Production and Protection, Obafemi Awolowo University, Ile-Ife.

DOI: https://doi.org/10.5281/zenodo.6573560

Published Date: 23-May-2022

Abstract: **Maize (*Zea mays* L.) is a multipurpose crop useful in human diet and animal feed. Maize yield improvement has continued to receive a lot of research attention, but less so for plant morphological characteristics especially considering the ongoing climate change impacts that have affected the response of many crops to the environment. The information that can be received from research on morphological traits could be critical, as it could enhance the efforts at ensuring proper crop adaptation to climate change, in addition to the direct or indirect contribution to grain yield. Five maize varieties were planted in randomized complete block design experiments and monitored in 8 environments at the Obafemi Awolowo University Teaching and Research Farm to examine the response of maize morphology to environments, seasons and weather factors. Result showed highly significant effect of environment on most measured traits ($P \leq 0.01$) with significantly higher means in the early season. Beyond the seedling stage, morphological traits responded positively to soil moisture, relative humidity, and solar radiation, On the contrary, soil heat flux, temperature, and heat unit negatively affected maize seedling growth.**

Keywords: **Climate change, crop phenology, crop physiology, growth analysis, seedling emergence and vigour.**

1. INTRODUCTION

Maize (*Zea mays* L.) remains a popular crop in sub-Saharan Africa (SSA) for its multifarious applications. It is the world's best-adapted crop and arguably the third most important crop after wheat (*Triticum aestivum*) and rice (*Oryza sativa*) (Bakht *et al.*, 2011), a feature that has endeared maize more to the relatively poor populations of SSA due mostly to the limited access to inputs. The demand for the different products of maize in Nigeria has continued to increase due to population growth and increased livestock production. Production of maize can be increased by increasing the area under cultivation and by intensifying cultivation i.e. through the use of improved agronomic practices and improved varieties (Fayose and Fakorede, 2014). Apart from its grains, maize plant has a good number of application to the industries especially in animal husbandry.

Maize yield (forage, fodder, grain, or stover) may be increased directly or indirectly by having fields with near perfect or perfect stands. A maize field with good stands can increase yield per unit area of land than one with non-perfect stands. In obtaining good stands in maize fields, growth at the seedling and vegetative stages of development i.e. good emergence percentage followed by high seedling vigor and robust vegetative growth, are imperative. In Nigeria as in most countries of the SSA, maize grain yield has received the most research attention, with much less attention paid to the general plant architiecture which could be critical in several applications, especially with the prevailing climate change scenarios, in addition to its direct or indirect contribution to yield. For instance, leaves play a critical role in plant nutrition through photosynthesis and other physiological activities. Maize canopy architecture, particularly leaf structure, has received little or no attention from researchers in SSA (Fayose *et al*., 2022). An improvement in leaf characteristics and efficiency to photosynthesise would potentially improve the general physical appearance and positively impact yield (Li *et al*., 2015). Traits including plant and ear heights cum general plant and ear aesthetics are important, as they facilitate production by allowing ease of mechanization, and also ensure higher economic returns from production per unit area of land. Because of the prevailing climate change, it becomes important to constantly evaluate and re-evaluate the current state of knowledge of crop physiology otherwise, currently sound information may be rendered obsolete within a short period of time. The impact of this on maize physiology has been reported at Ile-Ife, Nigeria (Fakorede and Akinyemiju, 2003).

Investigations have been done in most agro-ecologies of the world, on the response of grain yield to drought, salinity, density, weed stress, and nitrogen (Fuksa *et al*., 2004; Romdhane *et al*., 2016; *Song et al*., 2019) with just a hint rather than in-depth studies of morphological traits such as plant and ear height, leaf orientation, flowering and other morphological traits. Ajayo *et al*. (2021) studied the response of maize hybrids to plant density and nitrogen levels in multiple locations in Nigeria, and found that plant density rather than nitrogen level, significantly affected grain yield and most of the agronomic traits monitored in the study. Some of the morphological traits included plant height, ear height, and ratings of plant and ear aspect, but grain yield was the main focus of their environmental analysis. Lamidi and Afolabi (2016) examined the effects of environmental factors on leaf parameters and grain yield, and found significant influence of environmental factors on leaf arrangement, number, length, leaf area index, stem girth, and grain yield. The study, which was conducted in only one environment, did not examine seedling growth but included temperature, humidity, and wind direction as the only environmental factors considered. Very few studies have also attempted a relationship between maize morphology and climatic factors. In the present studies, five maize varieties were planted in eight environments during the early and late seasons at the Obafemi Awolowo University Teaching and Research Farm to test the hypothesis that environment, season and climatic factors do not affect maize morphological characteristics at any of the growth and developmental stages.

2. MATERIALS AND METHODS

The study was conducted at the Teaching and Research Farm of Obafemi Awolowo University, Ile-Ife (OAU TRF) in 2016 and 2017. In each experiment, five maize varieties (four OPVs and one single-cross hybrid), well adapted to the tropical rainforest environments, were planted in 3-replicate randomized complete block design. The OPVs included White DT STR SYN1 – TZL Comp. 1–W, TZL Comp. 4 DT F_2, TZL Comp. 1 C6/DT – SYN – 1 – W all of which were drought tolerant (DT) and of intermediate/late maturity, ACR 94 TZE Comp 5 C_3 (early maturing), and Oba Super 1, an intermediate-late single-cross hybrid obtained from Premier Seeds, Zaria. The four OPVs were obtained from the IITA Maize Improvement Program, and all five varieties are white-grained, high yielding and have been released for commercial production in Nigeria and several other West and Central African (WCA) countries.

The experiments were planted in eight environments (represented by planting dates), a total of four experiments each year. Environments 1, 2, 3 and 4 were planted on 24th March, 25th May, 24th August and 7th September of 2016, respectively, while Environments 5, 6, 7 and 8 were planted on 12th April, 14th June, 9th August and 23rd August of 2017, respectively. The first two environments each year belong to the early season while the last two each year are in the late season. Each plot contained six or four rows which were 5 m long and 0.75 m apart; within row spacing was 0.5 m. Seeds; properly treated with Apron* which contains thiamethoxam, mefenoxam (metalaxyl-M) and difenoconazole, to control damage by soil-borne diseases and insect pests; were sown, three per hill, after the experimental land had been ploughed and harrowed. Emergence counts were made daily from five to nine days after planting (DAP); from which emergence percentage (E%) and emergence index (EI) were computed as follows (Fakorede and Agbana 1983):

$$E\% = \frac{\text{Seedlings emerged in X DAP}}{\text{Total no of seeds sown)}} * 100$$

$$EI = \frac{\sum(\text{Plants emerged in a day}) * (\text{DAP})}{\text{Plants emerged by 9 DAP}}$$

ISSN 2349-7823

International Journal of Recent Research in Life Sciences (IJRRLS)
Vol. 9, Issue 2, pp: (71-78), Month: April - June 2022, Available at: www.paperpublications.org

Thinning was done following the emergence count at 9DAP to two plants per stand, with an estimated plant population density of 53, 333 plants ha^{-1}. Fertilizer was applied immediately after thinning at the rate of 60 kg ha^{-1} each for N, P_2O_5 and K_2O. Primextra, which contains atrazine (2-chloro-4- (ethyl amino)-6-isopropylamino-s-triazine) and alachlor (N-(methyl-2-methoxy-ethyl)-2-ethyl-8-methyl-chloroacetanilide) as active ingredients was applied as post-planting, maize pre-emergence herbicide at the rate of 5 l ha^{-1}. Further weed control was done using paraquat (N,N′-dimethyl-4,4′-bipyridinium dichloride), carefully applied as a post-emergence, non-selective and contact herbicide at the rate of 3.0 l ha^{-1}.

Data were collected on leaf angle (LA) and length for the upper and lower leaves. The upper leaf angle and length (LA_U, Leaf FP_U and Full Leaf LT_U) were determined using the leaf immediately above the ear, while the lower leaf angle and length (LA_L and Leaf FP_L and Full Leaf LT_L) were taken from the leaf immediately below the ear. Leaf angle was measured using a properly calibrated clinometer smartphone application (Pioneer, 2016); while the leaf length up to the flag point (Leaf FP_U and FP_L), and the full length (Full Leaf LT_U and LT_L) were measure using a flexible meter rule. Plant and ear heights (PHT and EHT) were obtained by measuring the distance from the soil surface to the first branch at the base of the tassel, and the node bearing the top ear for 10 random plants in each plot and their means taken as PHT and EHT per plot, respectively. Plants were rated at the latter part of grain filling for plant aspect (PASP) and at harvest for ear aspect (EASP). The ratings were done on a scale of 1-5 based on acceptability, aesthetics and overall health of plants and ears.

Data collected on grain yield were adjusted to 15 % moisture content. Minimum and maximum air temperatures and relative humidity, rainfall, soil moisture, solar radiation, net radiation, wind speed, soil temperatures (Ts 1 – 5), and soil heat flux were monitored from the automatic weather station (OAU MET Station) located on the OAU TRF. Heat unit was computed from the minimum and maximum temperature per day as given below:

$$\mathrm{HU} = \sum_{i=1}^{n} \left(\frac{\mathrm{Xi}^{\mathrm{H}} + \mathrm{Xi}^{\mathrm{L}}}{2} \right) 10$$

where X_i^L is the minimum temperature for the day (°C), X_i^H is the maximum temperature for the day (°C) ($X_i^H = 30$ if $X_i^H > 30$°C, $X_i^H = X_i^H$ if $X_i^H \leq 30$°C), and 10°C is the base temperature.

Plant aspect and EASP data were transformed using log to the e^{th} base. Analysis of variance was done on all measured traits using PROC GLM of Statistical Analysis System (SAS, 2000) following the linear additive model: $Y_{ijk} = \mu + \alpha_i + \beta_{j(i)} + \lambda_k + \alpha\lambda_{(ik)} + \varepsilon_{ijk}$, in which Y_{ijk} is the observed measurement of the k^{th} genotype grown in the j^{th} rep under the i^{th} environment; μ is the grand mean; α_i is the main effect of the i^{th} environment, i=1,2,..,8; $\beta_{j(i)}$ is the effect of the j^{th} replication nested within the i^{th} environment, j=1,2,3; λ_k is the effect of the k^{th} genotype, k=1,2,….5; $\alpha\lambda_{(ik)}$ is the first order interaction of the i^{th} environment with the k^{th} genotype, and ε_{ijk} is the random error (residual) term. Means were separated using Fischer's protected least significant difference (LSD) and Student's T-Statistic at 5% level of probability. Correlation analysis was also done on all measured traits; and between measured traits and climatic factors.

3. RESULTS

Results of the analysis of variance showed highly significant effects of environment and variety for all traits except full lower leaf lenght which did not show significant varietal effect (Table 1). There was significant environment by variety (ExV) interaction for emergence at 9DAP (E9), emergence index (EI), lower full leaf length (Full Leaf LT_L), plant (PHT) and ear (EHT) heights, plant aspect rating (PASP) and grain yield. It is unclear why this is so for Full Leaf LT_L but not for other leaf traits. Also, total leaf lenght (about 8% and 6% for upper and lower length, respectively) seems less likely to vary compared to other leaf variables as indicated by the CV values. Emergence percent, EI and PHT (about 7%, 3% and 8% for each, respectively) also recorded low CV values as opposed to grain yield (27%: Table 1).

ISSN 2349-7823

International Journal of Recent Research in Life Sciences (IJRRLS)
Vol. 9, Issue 2, pp: (71-78), Month: April - June 2022, Available at: www.paperpublications.org

Table 1A: Mean squares from the ANOVA of morphology traits of five maize varieties evaluated in eight environments at the OAU TRF in 2016 and 2017.

Source	DF	E9	EI	LA_U	LA_L	Leaf FP_U	Leaf FP_L
Environ(E)	7	3091.97**	5.45**	190.11**	116.01**	632.26**	915.56**
Variety (V)	4	4046.05**	1.20**	534.94**	296.66**	122.16*	108.97**
Rep/Env	16	310.64**	0.09	17.13	11.76	37.79	54.13*
ExV	28	843.15**	0.22**	13.28	19.16	45.34	36.83
Error	64	26.7596	0.05	46.96	14.14	41.43	87.43
Total	119	572.42	0.45	23.00	30.49	79.33	25.98
CV		7.35	3.44	16.21	15.29	17.26	10.73

*, ** = F - Statistic significant at 0.05 and 0.01 level of probability, respectively.

DF = degree of freedom

CV = coefficient of variation

E9 = emergence percent at 9DAP (%), EI = emergence index (days), LA_U = upper leaf angle (degree), LA_L = lower leaf angle (degree), Leaf FP_U = upper leaf lenght up to the flag point (cm), Leaf FP_L = lower leaf lenght up to the flag point (cm)

Table 1B: Mean squares from the ANOVA of morphology traits of five maize varieties evaluated in eight environments at the OAU TRF in 2016 and 2017.

Source	DF	Full Leaf LT_U	Full Leaf LT_L	PHT	EHT	PASP	EASP	YIELD (t/ha)
Environ(E)	7	1053.68**	1090.58**	9344.26**	3346.22**	0.05**	0.04**	7.53**
Variety (V)	4	85.47*	24.23	877.25**	249.22*	0.01*	0.03**	0.83*
Rep/Env	16	34.26	43.34*	381.49**	176.38*	0.01	0.01	0.48*
ExV	28	50.02	42.98**	292.54**	181.15**	0.01*	0.005	0.72**
Error	64	27.99	20.97	143.73	80.66	0.004	0.01	0.26
Total	119	96.27	92.18	776.57	314.94	0.008	0.01	0.84559
CV		8.75	6.54	7.95	14.57	13.55	16.95	27.54

*, ** = F - Statistic significant at 0.05 and 0.01 level of probability, respectively.

DF = degree of freedom

CV = coefficient of variation

Full Leaf LT_U = full upper leaf lenght (cm), Full Leaf LT_L = full lower leaf lenght (cm), PHT = plant height (cm), EHT = ear height (cm), PASP = plant aspect rating, EASP = ear aspect rating

For mean analysis (Table 2), we include representative traits in each group to keep the tables as comprehensive as possible. Although Env 3, a late season environment had the highest mean value for E%, it was not the fastest to attain its maximum E%, as Env 2 an early season environment, with the next highest value for E%, even though significantly lower than Env 3, had the fastest speed of emergence (EI). Env 7 in the late season had the lowest E% value while Env 5, an early season environment was slowest for EI. It seems however, that late season environments were more favourable for E% and EI from their relative positions in the mean rank. Envs 6, 4 and 1 had the widest leaf angles (LA_U and LA_L), while Envs 7, 3 and 2 had the lowest LA angles. Early season seemed to produce plants with wider LA than late season in contrast to emergence (Table 2). Leaf length (flag point and full length) generally seemed to be longer too in the early season than late season as Envs 1, 2 and 5 were consistent at the top end of the mean table across all leaf indices. Similar trend were observed for grain yield along with plant and ear heights as Envs 1, 2 and 5 were again prominent for higher grain yield, higher ear placement and taller plants overall. Plant and ear aspect ratings did not seem to follow a particular trend for environment in the two seasons (Table 2).

ISSN 2349-7823

International Journal of Recent Research in Life Sciences (IJRRLS)
Vol. 9, Issue 2, pp: (71-78), Month: April - June 2022, Available at: www.paperpublications.org

Analysis of mean performance of the different traits across each of the two seasons confirmed that the late season indeed favoured seedling emergence and vigour with significantly higher mean value observed for E% and lower value for EI (lower value = faster speed) in the late season (Table 3). Conversely, wider angles and increased length are expected for leaves in the early season. Plant and ear aspect ratings were also significantly superior in the early season. However, plant and ear heights along with grain yield appear neutral to season effect.

Table 2: Ranking of eight environments for mean values of plant morphology indices of five maize varieties monitored in eight environments at the OAU TRF in 2016 and 2017.

Rank	E9ɸ		LA_U		Leaf FP_U		Full Leaf LT_L		PHT		PASP		EASP		YIELD (t/ha)	
	Env†	Mean	Env	Mean	Env	Mean	Env	Mean	Env	Mean	Env	Mean	Env	Mean	Env	Mean
1	3	92.96	6	34.43	1	46.78	2	83.99	1	185.4	2	2.32	5	2.37	1	3.18
2	2	85.76	4	33.20	2	43.47	5	75.64	5	178.8	5	2.43	4	2.52	5	2.39
3	4	81.01	1	32.39	5	41.66	1	75.10	2	168.8	8	2.68	1	2.80	2	2.10
4	1	67.81	5	30.23	7	38.93	7	70.95	4	151.7	4	2.95	7	2.82	4	1.97
5	8	64.34	8	28.85	8	35.05	3	70.57	6	141.1	3	3.11	8	3.02	3	1.43
6	6	58.92	2	26.97	3	32.69	8	65.29	8	138.9	6	3.21	6	3.07	8	1.43
7	5	56.20	3	25.36	4	31.96	4	61.44	7	121.9	7	3.26	2	3.25	7	1.34
8	7	55.96	7	25.26	6	27.78	6	57.40	3	119.5	1	3.33	3	3.25	6	0.97
LSD		3.77		3.50		4.70		3.34		8.7		0.05		0.06	LSD	0.37

LSD = least significant difference

† - Env = Environment

ɸ E9 = emergence percent at 9DAP (%), LA_U = upper leaf angle (degree), Leaf FP_U = upper leaf lenght up to the flag point (cm), Full Leaf LT_L = full lower leaf lenght (cm), PHT = plant height (cm), PASP = plant aspect rating, EASP = ear aspect rating

Table 3: Means and t-statistic values of different plant morphology traits of maize evaluated over eight environments in the early and late seasons of 2016 and 2017 at the OAU TRF.

Season	E9ɸ	EI	LA_U	LA_L	Leaf FP_U	Full Leaf LT_U	Leaf FP_U	Full Leaf LT_L	PHT_	EHT	PASP	EASP	Yield (t/ha)
Early	67.17	6.87	31.00	26.10	39.92	63.92	49.85	73.03	168.53	68.80	2.79	2.85	2.16
Late	73.57	6.71	28.17	23.10	34.66	57.06	45.16	67.06	132.97	54.50	2.99	2.89	1.54
Δmean	6.40	0.16	2.84	2.99	5.26	6.86	4.70	5.97	35.57	14.30	0.21	0.04	0.62
t-Statistic	22.00*	86.78**	20.87*	16.44*	14.17*	17.63*	20.21*	23.47*	8.48	8.62	29.81*	169.79**	5.99

*,**- Significant at 0.05 and 0.01 level of probability, respectively.

ɸ - See Table 1

Results from the correlation analysis of all measured traits revealed that E%, EHT and grain yield were the only plant traits significantly influenced by weather factors (Table 4). Emergence appears to be affected by heat as E% scored significant negative correlations with soil heat flux, heat unit, minimum and mean air temperatures as well as heat unit; but enhanced by soil moisture and maximum relative humidity. What is strange however, is that emergence did not show any significant relationship with rainfall given rainfall is the only water source at the location; and with soil temperature despite its significant relationship with soil heat flux. The higher the soil temperature at levels 4 and 5, and mean global radiation, the higher up the stem the ear placement. The higher the relative humidity on the other hand, the lower the position of ear on the stem. Grain yield also seems strongly promoted by increased total global radiation (Table 4).

ISSN 2349-7823

International Journal of Recent Research in Life Sciences (IJRRLS)
Vol. 9, Issue 2, pp: (71-78), Month: April - June 2022, Available at: www.paperpublications.org

Table 4: Correlation coefficients of some plant traits of five maize varieties with weather factors monitored in 8 environments at the OAU TRF.

	E9$^{\phi}$	EHT	YIELD (t/ha)
Soil temperature 1	-0.40	0.72	0.58
Soil temperature 2	-0.53	0.79	0.58
Soil temperature 3	-0.50	0.81	0.66
Soil temperature 4	-0.52	0.81*	0.71
Soil temperature 5	-0.54	0.83*	0.77
Soil heat flux	-0.97**	0.08	-0.06
Soil moisture	0.86*	-0.40	-0.01
Rainfall	0.70	-0.38	0.16
Wind speed	-0.30	0.02	0.30
Mean air temperature	-0.88*	0.26	0.06
Minimum temperature	-0.96**	0.10	-0.04
Maximum temperature	-0.77	0.42	0.18
Heat unit	-0.96**	-0.28	-0.01
Mean relative humidity	0.84*	-0.54	-0.25
Minimum humidity	0.52	-0.88*	-0.36
Maximum humidiy	0.97**	-0.20	-0.23
Net radiation	-0.18	0.74	0.58
Mean global radiation	-0.36	0.84*	0.81
Total global radiation	-0.36	0.74	0.95**

*,**- Significance at 0.05 and 0.01 level of probability, respectively.

ϕ - See Table 1

global solar radiation, net radiation and soil heat flux are in Wm^{-2}; temperature is in ^{o}C, soil temperatures 1 – 5 are soil temperatures at different levels (2cm, 5cm, 10 cm, 20cm and 50cm for soil temperatures 1, 2, 3, 4 and 5, respectively), soil moisture is in m^3/m^3, rainfall is in mm, windspeed is in m/s, relative humidity is in %.

In a similar vein, plant traits with significant correlation coefficients are presented in Table 5. Plants with wide LA_U would also have wide LA_L and vice-versa; ditto for leaf FP_U and full leaf LT_U. A taller plant would also seem to have higher ear placement, and would seem to receive low plant and ear aspect ratings, and subsequently, higher grain yield (Table 5).

Table 5: Correlation coefficients among plant traits of five maize varieties monitored in eight environments at the OAU TRF in 2016 and 2017.

	LA_L^{ϕ}	Full Leaf LT_U	Full Leaf LT_L	EHT	PASP	EASP	Yield (t/ha)
E9	-0.38	-0.47	-0.08	-0.11	0.20	0.36	0.02
LA_U	0.91*	-0.62	-0.71	0.27	-0.14	-0.32	0.08
LA_L	1	-0.55	-0.73	-0.04	0.004	-0.06	-0.23
Leaf FP_U		0.96**	0.89*	0.55	-0.55	-0.57	0.63
Full Leaf LT_U		1	0.91	0.32	-0.41	-0.37	0.42
Leaf FP_L			0.90	0.61	-0.46	-0.52	0.78
Full Leaf LT_L			1	0.37	-0.43	-0.30	0.55
PHT				0.86*	-0.80	-0.81	0.78
EHT				1	-0.81*	-0.90*	0.96**
PASP					1	0.57	-0.77
EASP						1	-0.84
Yield (t/ha)							1

*,**- Significance at 0.05 and 0.01 level of probability, respectively.

ϕ - See Table 3

4. DISCUSSION

The study evaluated the effect of season and enviroment on maize morphological traits in the tropical rainforest of sw Nigeria. Results revealed that environment greatly influenced the performance of each morphology trait assayed in this study. According to Fayose and Fakorede (2021b), environmental conditions vary widely from day to day and from one environment to the other due to temporal and spatial variations in climatic factors such as temperature, precipitation, solar radiation, evapotranspiration, relative humidity, and edaphic factors relating to soil conditions. For instance, environments 3, 5 and 8 received 412 mm 458 mm and 208 mm total rainfall respectively; 26.6 MW/m^2, 30.5 MW/m^2 and 26.6 MW/m^2 total global radiation respectivley. A large proportion of the total sum of squares was also due to the environment alone. Fakorede (1985) found at Ile-Ife that yield decreased by 30, 38 and 34 kg ha^{-1} for each day by which sowing was delayed after the first planting in March of 1978, 1980 and 1981 respectively. The study attributed the decrease to reduced plant and ear height, tassel weight, branch number, and small overall plant size including reduction in values of some yield components; and suggested early planting of maize with the first few rains in the early season to ensure optimum yield. Oluwaranti *et al*. (2008) evaluated the grain yield performance of different maturity groups of maize varieties at different planting dates at the same location and found that grain yield and yield components decreased with delayed planting in the late season. Unfortunately, that study did not include any plant morphology trait. In the Sudan savanna zone, for example, Jibrin *et al*. (2012) found earlier part of the late season as the optimum planting window for maize although they too did not assay any maize morphology trait in the study. The early season was implicated for better overall performance of the morphology traits except for emergence traits which were seemingly enhanced by the conditions of the late season in this study. the reason for this result is not immediately obvious but could be due to the high volume of rainfall usually received in the late season, as the peak amount of rainfall is usually recieved around October at this ecology, although none of the experiments was planted in October and result also did not establish a significant correlation of rainfall with emergence despite the significant E% correlation with relative humidity. The relationship of the morphology traits with climatic factors also indicated a modest effect of climate, a prominent factor of the environment, on maize plant morphology traits including E% and EHT, even though none of the leaf parameters scored significant correlations with weather factors. Fayose and Fakorede (2021b) found that planting maize early in March/April of the early season and late July/early August of the late season would ensure maximum grain yield. The present study suggest that the highest overall yield of maize could only be obtained in the early season at this location even though grain yield was neutral to season effect. While only few of the traits assayed in this study scored significant correlations with grain yield, it is important to note that a lot of these traits when positively present would improve yield indirectly. For instance, severe and prolonged water stress at the seedling stage may damage the structure of the photosynthetic membrane resulting in lower chlorophyll content and thus, low radiation use efficiency (RUE, Song *et al*., 2019). Maize plant with such damage often did not show meaningful recovery irrespective of the amount of moisture supplied at the latter stages. Therefore, unrecoverable yield loss could occur if adequate attention is not paid to growth at the seedling stage. Also, there was no significant correlation of the leaf indices with solar radiation but yield was highly correlated with solar radiation. It is a fact, Nonetheless, that the major site of plant nutrition is the leaf. It is strange therefore that there is no correlaton with solar radiation as photosynthesis, the process through which green plants manufacture their food, happens mainly in the leaf and is powered by the photosynthetically active spectrum of the solar radiation (PAR). Therefore, even though there is no direct relationship in this study, it would be reasonable to assume that the overall health including the physical and chemical conditions of the leaf would greatly influence the grain yield of the crop. Also, a healthy, vigorously growing plant with good values for all the traits assayed in this study would have better chance of surviving and thriving in case of exposure to different environmental stresses (biotic or abiotic; Fayose and Fakorede, 2014) including lodging, sudden dry spell, attack by diseases and pests, among other, all of which have become aggravated by climate change. Therefore, it is important to find ways of ensuring those traits are constantly improved in crops as they would contribute directly to yield when grain yield is not the target, and directly or indirectly to grain yield.

In conclusion, there were variable response of maize morphology characteristics examined in this study to environment and season; and maize crop response to environment and season is not the same at all growth stages. Late season favoured seedling emergence and vigour; while the early season favoured vegetative growth and plant development. There was, however, no significant season effect on grain yield. Climatic factors within the early season that affected seedling growth are soil heat flux, mean and minimum temperatures and heat unit; while soil moisture and relative humidity favoured seedling growth in the late season. The major climatic factor favouring maize plant at the vegetative and developmental stages is solar radiation, others are soil temperature and average radiation. It implies that planting maize in the early season would enhance plant vigour and result in better overall aesthetics and health which would boost yield directly or indirectly depending on the form of yield desired.

REFERENCES

[1] Ajayo, B. S., Badu-Apraku, B., Fakorede M. A. B. & Akinwale, R. O. (2021). Plant density and nitrogen response of maize hybrids in diverse agroecologies of West and Central Africa. *Aims Agriculture and Food*, 6 (1), 381 – 400.

[2] Bakht, J., Shafi, M., Rehmam, H., Uddin, R. & Anwar, S., (2011). Effect of planting methods on growth, phenology and yield of maize varieties.*Pakistan Journal of Botany*, 43(3):1629-1633.

[3] Fakorede, M.A.B. (1985). Response of maize to planting dates in a tropical rainforest location. *Experimental Agriculture, 21*, 19-30.

[4] Fakorede, M.A.B. & Agbana, S.B. (1983). Heterotic effects and association of seedling vigor with mature plant characteristics and grain yield in some tropical maize cultivars. *Maydica, 28*, 327-338.

[5] Fakorede, M. A. B. & Akinyemiju, O. A. (2003). Climate change: effects on maize production in a tropical rainforest location. P. 272-282. In Badu-Apraku, B., Fakorede, M. A. B., Ouedraogo, M., Carsky, R.J. and Menkir, A. (Eds.). Maize revolution in West and Central Afica. P*roceedings of a Regional Maize Workshop*, IITA-Cotonou, Benin Republic. 14-18 May 2001. WECAMAN/IITA.

[6] Fayose, C.A. & Fakorede M.A.B. (2014). Growth analysis of maize varieties at the seedling and vegetative developmental stages. *Proceedings of the Genetics Society of Nigeria Conference*, Rubber Research Institute, Benin, Edo State, Nigeria, October 20-24. pp 425-429.

[7] Fayose, C. A., Fakorede, M. A. B., Badu-Apraku, B. and Abebe, M. (2022). Canopy architecture and grain yield of maize in the rainforest of Southwestern Nigeria. Manuscript submitted to *Field Crop Research*.

[8] Fayose, C. A. & Fakorede M. A. B. (2021). Planting date effects on maize (*Zea mays* L.) growth and development in the rainforest of southwestern Nigeria. *Acta Agriculturae Slovenica*, 117 (1), 101 -109.

[9] Fuksa, P., hakl, J. Kocourkova, D. & Vesala, M. (2004). Influence of weed infestation on morphological parameters of maize. *Plant Soil Environment*, 50(8), 371 – 378.

[10] Jibrin M. J., Kamara, A.Y. & Ekeleme, F. (2012). Simulating planting date and cultivar effects on dryland maize production using CERES-maize model**.** *African Journal of Agricultural Research, 7*(40), 5530-5536

[11] Li, C., Li, Y., Shi, Y., Song, Y., Zhang, D., Buckler, E. S., Zhang, Z., Wang, T. & Li, Y. (2015). Genetic control of the leaf angle and leaf orientation value as revealed by ultra-high density maps in three connected maize populations. *PLOS One Journal* 10(3): e0121624.

[12] Oluwaranti, A., Fakorede, M.A.B. & Badu-Apraku, B. (2008). Grain yield of maize varieties at different maturity groups under marginal rainfall conditions. *Journal of Agricultural Sciences, 58*(8), 183 - 191.

[13] Pioneer, (2016). Corn leaf architecture response to plant density. *Pioneer® GrowingPoint® Agronomy.*Published online at https://www.pioneer.co m/home/site/mobile/pioneer growingpoint_agronomy/corn_leaf_architecture/

[14] Romdhane, L., Dal, C. C., Vamerali, T & Radhouane L. (2016). Effect of drought and salinity o maize phenology, morphology and productivity in a semi-arid environment. *Italian Journal of Agrometeorology*, 3, 43 – 54.

[15] SAS Institute Inc. (2000). "*Base SAS® 9.0 Procedures Guide*." Cary, NC: SAS Institute Inc.

[16] Song, L., Jin, J. & He, J. (2019). Effect of severe water stress on maize growth process in the field. *Sustainability*, 11, 1-18.