Original Research Article

The Impacts of Climatic Variability on the Grain Yield Performance of Open Pollinated Varieties (OPV) of Maize in a Rainforest Location of Nigeria

ABSTRACT

Aims: The objectives of the study were to examine the effects of climatic factors on maize yield and identify best planting date for maize in Rainforest Agroecology of Nigeria.
Study design: Grain yield of seventeen open pollinated varieties of maize evaluated in 21 randomly selected environments in the Rainforest Agroecology of Nigeria were used for the study. Each field experiment was laid out in a randomized complete block design with four replications and 5 m long single-row plots spaced at 0.75 m apart and three seeds were planted 0.5 m apart within the row
Place and Duration of Study: Grain yield of 17 maize varieties evaluated at the Obafemi Awolowo University Teaching and Research Farm (7°28'N, 4°33'E, altitude 224 m above sea level) during the late cropping seasons of 2001, 2005 and early cropping seasons of 2002, 2006 were used for this study
Methodology: The grain yield and climatic data within the period of evaluation was subjected to Analysis of variance and correlation analysis.
Results: Rainfall alone significantly accounted for over 42 % of the total variation on grain yield across the environments while combination of two climatic factors revealed significant variation across the combination ranging from over 41 % to 45 % with minimum relative humidity and Maximum temperature together having the highest significant variation on grain yield of Maize. There was also highly significant positive correlation between grain yield and total rainfall (r = 0.65**) and minimum relative humidity (r = 0.64**).
Conclusion: Ranking of the twenty-one environments for average grain yield, the most favourable planting date ranged from early April to early May in Rainforest Agro-ecology of Nigeria

Keywords: climate; change; variability; maize; performance; calendar dates; growth; yield.

1. INTRODUCTION

Maize (*Zea mays* L.) is a major staple and Africa dominant food crop, and its importance has been increasing rapidly during the last two decades with potential yield of 6 tons per hectare in Nigeria [1]. In Nigeria, maize is arguably the third most widely cultivated cereal crop after guinea corn or sorghum (*Sorghum bicolor* (L.) Moench) and millet (*Pennisetum spp.*) to serve as largest maize producer in Africa with estimated 12.7 million tonnes per annum [2]. Improved Maize Varieties are released in the country with good value addition for alleviating the food security challenges in West and Central Africa (WCA) countries [3]. However, actual yields of maize are significantly reduced compared to the potential yields due to biotic and abiotic stress factors against which breeders have been developing and releasing resistant or tolerant varieties.

In order to effectively mitigate all these constraints so as to have high agricultural productivity, the ultimate goal of plant breeders in a crop improvement program must be development of varieties with high yield potential, large seed size, and resistance to major pests and diseases and, most importantly, highly stable performance and broad adaptation over ranges of environments. Farmers and scientists desire successful new maize genotypes that are high yielding with desirable agronomic traits.

An estimated 15 % to 20 % of maize grain yield is lost each year due to drought and such losses may further increase as drought becomes more frequent and severe because of climate change [4]. Climatic variation plays the major roles for populations and species to persist over evolutionary period of time, the country; Nigeria is with highly diverse climatic weather conditions and with different soil types which serve as drivers behind the rise in food insecurity across the nation. These variations in climatic factors had adversely affected maize yield and its productions over the years and there is urgent need to determine the performance of maize varieties under the resilient climate change in the rainforest agro-ecology of Nigeria for effective and sustainable maize production in the agro-ecology of the country. Therefore, the objectives of the study were to examine the climatic factors affecting maize yield in rainforest agroecology of Nigeria and to identify most favourable planting calendar date for maize adaptation in the rainforest agroecology of Southwestern Nigeria.

2. MATERIAL AND METHODS

Grain yield data of 17 open pollinated varieties (OPV) of maize obtained from maize breeding program of IITA-Ibadan were used for this study (Table 1).

Table 1: Seventeen maize varieties evaluated at the Teaching & Research Farm, Obafemi Awolowo University (OAU), Ile-Ife in the late seasons of 2001, 2005 and early seasons
3 of 2002, 2006.

S/N	Names	Maturity group	Special characteristics
1	TZECOMP3DT	Early	SR, DT
2	ACR 90POOLI6-DT	Early	SR, DT
3	TZEE-SrxDamascus	Extra-Early	SR
4	TZEE-SRBC5	Extra-Early	SR
5	HEI97TZE COMP4C3	Early	SR
6	TZECOMP3x4C2	Early	SR
7	ACR 95TZE COMP4C3	Early	SR
8	ACR 9931-DMRSR	Early	SR, DMR
9	TZE-WPOPx1368STRCl	Early	SR, STR
10	DMR-ESR Y CIF2	Early	SR, DMR
11	TZECOMP4C2	Early	SR
12	DMR-ESRWCIF2	Early	SR, DMR
13	BAG 97TZECOMP3x4	Early	SR
14	AK95DMR-ESRW	Early	SR, DMR
15	EV 8435-SR	Intermediate/Late	SR
16	Sin 9432	Intermediate/Late	SR
17	EV 32-SR	Intermediate/Late	SR

SR=streak resistant, DT=drought tolerant, DMR=downy mildew resistant.

The 17 maize varieties were evaluated at the Obafemi Awolowo University Teaching and Research Farm (7°28'N, 4°33'E, altitude 224 m above sea level) during the late cropping seasons of 200l, 2005 and early cropping seasons of 2002, 2006 (Table 2).

Table 2: Planting dates representing the 21 environments in a 4-year period at the Teaching and Research Farm of Obafemi Awolowo University, Ile-Ife.

S/N	Environment	Planting Date
1	E1	20/08/2001

2	E2	27/08/2001
3	E3	03/08/2001
4	E4	10/09/2001
5	E5	17/09/2001
6	E6	13/03/2002
7	E7	20/03/2002
8	E8	27/03/2002
9	E9	03/04/2002
10	E10	10/04/2002
11	E11	17/04/2002
12	E12	24/04/2002
13	E13	07/09/2005
14	E14	14/09/2005
15	E15	21/09/2005
16	E16	03/04/2006
17	E17	10/04/2006
18	E18	17/04/2006
19	E19	24/04/2006
20	E20	01/05/2006
21	E21	08/05/2006

Climatic data for each period of planting to harvesting was collected from the Nigerian Meteorological Services (NIMETS), Oshodi, Lagos, Nigeria to quantify the variability of the environments. Each field experiment was laid out in a randomized complete block design with four replications and 5 m long single-row plots spaced at 0.75 m apart and three seeds were planted 0.5 m apart within the row. Best agronomic practice was engaged during the experiment. Grain yield was calculated by adjusting to 15 % moisture content (MC) and at 80 % shelling percentage as given in the following equation:

$$Grain\ yield, \frac{tons}{ha} = \frac{FW}{3.75}\ x\ \frac{(100 - MC)}{85}\ x\ \frac{(10{,}000)}{Plot\ size}\ x\ \frac{80}{100}$$

FW = Field weight per plot, 3.75 = Size of the plot and MC = Moisture content

The grain yield of the OPV of maize were subjected to Analysis of variance (ANOVA), Correlation and regression analysis was done for the maize grain yield and the climatic factors. Ranking of each variety and each environment was done using confident limit to test significance of the varieties from one another and the environments from one another.

3. RESULTS AND DISCUSSION

Analysis of Variance and Percent Contributions to Variation

The combined ANOVA for the grain yield showed significant ($P \leq 0.05$) or highly significant ($P \leq 0.01$) environment, genotypic and genotype x environment interaction effects (Table 3). Partitioning the total sum of squares into proportions contributed by each source of variation indicated 52.74 % for environment, 4.10 % for genotype, 13.27 % for genotype x environment interaction, and 23.54 % for the random error (Table 3). The fact that ANOVA showed highly significant differences among the maize varieties in this study is evidence of high variability among the OPV of maize varieties which may be due to different maturity groups of the maize varieties and the different purposes for which the varieties were developed (Resistance/tolerance to diseases/Insect Pest or high Yield). This is consistent with studies conducted by maize breeders all over the world both for OPVs [5,6,7,8] and all types of hybrids [9,10,11].

Table 3: Combined ANOVA for grain yield and the percentage of total sum of squares (% SS) attributable to each source of variation for 17 OPVs evaluated in 21 environments over a period of four years at Obafemi Awolowo University Teaching & Research Farm, Ile-Ife, Nigeria**.**

Source of variation	DF	Sum of squares	Mean squares	%SS
Environment (E)	20	2681.77	134.0885**	52.73651
Rep-within-E	63	270.4524	4.292895**	5.318396
Genotype (G)	16	208.7292	13.04558**	4.104622
G x E	320	674.6502	2.108282**	13.26687
Error	951	1197.235	1.258922	23.5434

The ANOVA result also clearly justified the use of diverse environments observed in this study for assessment of climatic study of grain-yield performance of OPV of maize in the rainforest agroecology of Nigeria as highest contributor to the variation which could be due to large differences occurring in climatic factors such as amount and distribution pattern of rainfall, temperatures, solar radiation, incidence of diseases and pests as well as the soil type.

Ranking of Environments and Genotypes

Ranking of the 21 environments based on the computation of confidence limits for average grain yield showed these environments with the following calendar dates; 24/04/2006, 24/04/2002, 01/05/2006, 17/04/2002, 10/04/2006 and 17/04/2006 (Table 2) as the most favorable with mean yield significantly higher than overall mean yield while environments with the following dates; 17/09/2001, 21/09/2005, 08/05/2006, 10/09/2001 and 03/04/2006 (Table 2) were the most unfavorable with mean yield significantly lower than overall average yield (Table 4).

Table 4: Ranking (best=1) of grain yield performance (t ha^{-1}) of 17 OPVs evaluated in 21 environments in a 4-year period at the Teaching and Research Farm of Obafemi Awolowo University, Ile-Ife, Nigeria.

Environmental ranking			Varietal ranking		
Rank	Environment (Calendar Date)	Mean yield	Rank	Variety	Mean yield (t ha^{-1})
1	24/04/2006	5.39	1	ACR 90POOLI6-DT	3.09
2	24/04/2002	4.89	2	TZEE-SRBC5	3.06
3	01/05/2006	4.26	3	ACR 9931-DMRSR	2.95
4	17/04/2002	4.04	4	TZECOMP3x4C2	2.94
5	10/04/2006	3.91	5	HEI97TZE COMP4C3	2.85
6	17/04/2006	3.85	6	TZE-WPOPx1368STRCl	2.76
7	13/03/2002	3.60	7	BAG 97TZECOMP3x4	2.76
8	20/03/2002	2.95	8	Sin 9432	2.75
9	03/04/2002	2.9	9	TZECOMP3DT	2.7
10	27/03/2002	2.63	10	AK95DMR-ESRW	2.67
11	27/08/2001	2.51	11	EV 8435-SR	2.5
12	03/08/2002	2.14	12	ACR 95TZE COMP4C3	2.47
13	14/09/2005	1.93	13	TZEE-SRxDamascus	2.46
14	07/09/2005	1.62	14	DMR-ESR Y CIF2	2.32
15	10/04/2002	1.59	15	DMR-ESRWCIF2	2.25
16	20/08/2001	1.55	16	EV 32-SR	1.77
17	03/04/2006	1.40	17	TZECOMP4C2	1.64
18	10/09/2001	1.25		Mean Yield	2.58
19	08/05/2006	0.94		MSGen	13.05
20	21/09/2005	0.54		SEM	0.21
21	17/09/2001	0.38		Confidence Limits	2.16 - 3.00
	Mean Yield	2.58			
	MSEnv	138.08			
	SEM	0.57			
	Confidence Limits	1.44-3.72			

From the above partitioning of the environments, the favourabe planting date for OPV of maize ranges from early April to early May in Southwestern Nigeria. Also, Varietal differences for grain yield were also observed with varieties ACR 90POOLI6-DT and TZEE-SRBC5 having 3.09 t ha^{-1} and 3.06 t ha^{-1} respectively as the highest yielding varieties with their yield significantly higher than average yield (2.6 t ha^{-1}), while TZECOMP4C2 and EV 32-SR (1.6 t ha^{-1} and 1.8 t ha^{-1}, respectively) were the lowest yielding varieties as they had significantly lower yield than overall mean yield (Table 4). This could be due to steady rainfall pattern that collide with high intensity of sunshine during these times for good vegetative growth and effective photosynthesis for the maize varieties with the resultant effect on grain yield.

The climatic factors varied widely among the environments with the total amount of rainfall during the seasons ranging from 282.50 mm to 607 mm. Among the climatic factors, rainfall alone significantly accounted for over 42 % of the total variation in grain yield across the environments and follow significantly by minimum relative humidity with about 41 % (Figures 1 & 2).

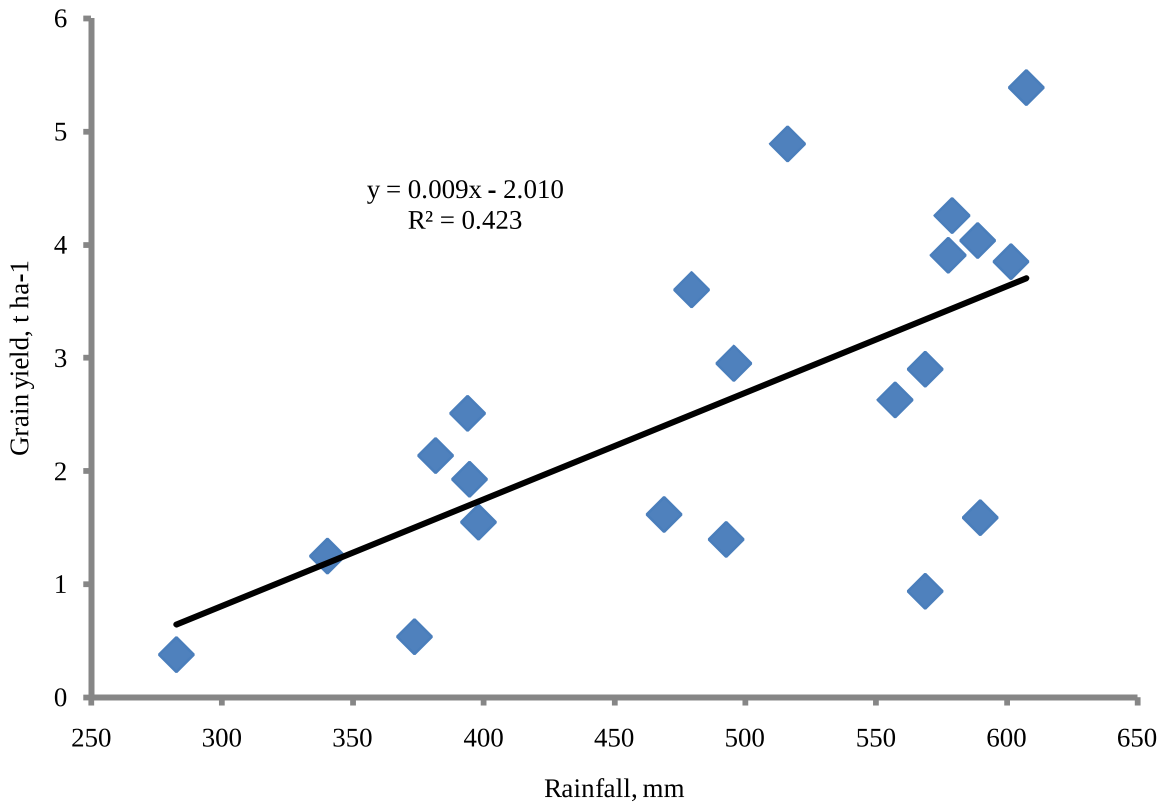

Figure 1: Response of grain yield to rainfall variation of the 17 maize OPVs evaluated in 21 environments over a period of four years in the rainforest Agroecology of Southwest Nigeria.

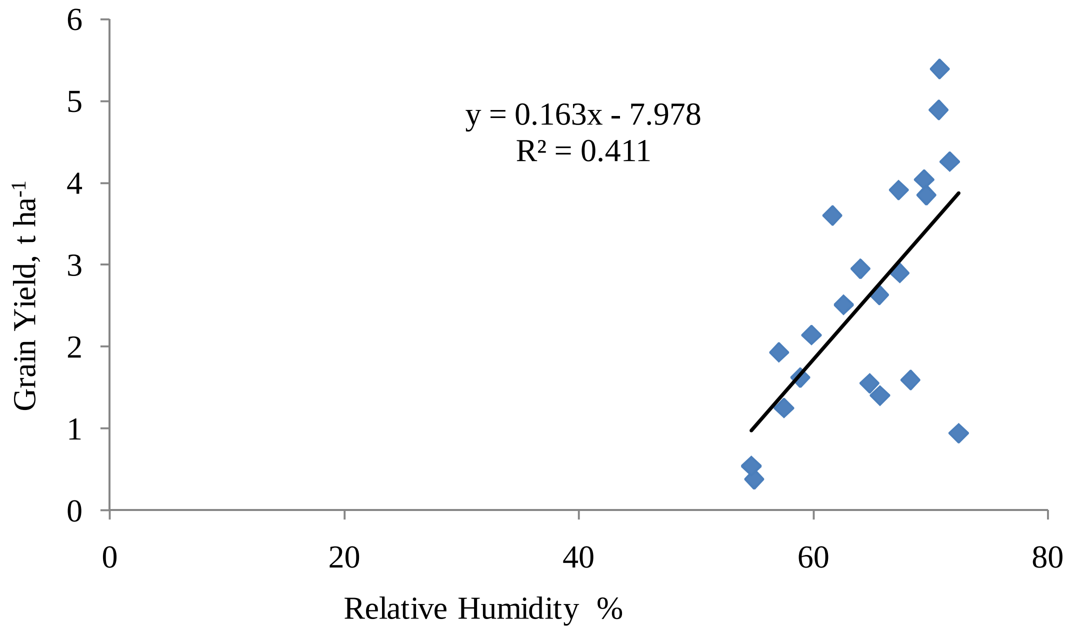

Figure 2: Response of grain yield to relative humidity variation in the environments used for evaluation of 17 maize OPVs in the rainforest Agroecology of Southwest Nigeria over a 4-year period.

Combination of the two most significant climatic factors with other factors measured in this study revealed significant variation across the combination ranging from over 41 % to 45 % with minimum relative humidity and Maximum temperature having the highest significant variation on grain yield of Maize (Table 5).

Table 5: Climatic effects on grain yield of OPVs of Maize evaluated in 21 environments over a period of four years in the Rainforest Agroecology of Southwest Nigeria.

Variables	r^2	**Variables**	R^2
MaxTemp	0.247*	Rain-RH(15Z)	0.444**
MinTemp	0.055	Rain-RH(09Z)	0.432**
MeanTem	0.000	Rain-MaxT	0.433**
Heat Unit (HU)	0.234*	Rain-MinT	0.423**
Rainfall (Rain)	0.423**	Rain-MeanT	0.426**
RH(09Z)%	0.282*	Rain-Wspd(09Z)	0.430**
RH(15Z)%	0.411**	Rain-Wspd(15Z)	0.427**
Wspd(09Z)	0.303**	Rain-HU	0.424**
Wspd(15Z)	0.208*	RH15-Wspd(09Z)	0.438**
		RH15-MaxT	0.450**
		RH15-MinT	0.412**
		RH15-MeanT	0.418**
		RH15-HU	0.449**
		RH15-Wspd(15Z)	0.412**

RH15-Wspd(09Z)	0.438**
Overall R^2	0.485

RH(09Z)- Low relative humidity; RH(15Z)- High relative humidity; Wspd(09Z) – Low wind Speed, Wspd(15Z) – High wind speed, MaxT – Maximum Temperature, MinT – Minimum Temperature, MeanT – Mean Temperature; HU – Heat Unit; r^2 – coefficient of determination for simple regression; R^2 – coefficient of determination of multiple regression;

The variation in grain yield of OPV of maize was highly correlated with both total rainfall during the cropping season (r = 0.65**) and minimum relative humidity (r = 0.64**) in which both factors were closely related (r = 0.88**) and accounted for the highest variation among the climatic factors affecting maize grain yield in rainforest agro-ecology of Nigeria. This simply implied that increase in the amount of rainfall increase relative humidity significantly and thereby help maize crop in grain-filing mechanism for better grain yield. In addition, maximum relative humidity, wind speed, maximum temperature and heat units had significant positive correlation coefficients ranging from 0.45 to 0.55 with grain yield (Table 6). The influence of climatic variability on the performance of OPV of maize both in yield and stability/adaptability can be very momentous especially under rainfed agriculture in Southwestern Nigeria as it may be responsible for the significant G x E interaction. The significant effects of climatic factors on the environments in this study corroborate the findings of several studies conducted at the same location over many years. Using path analysis on yield data collected from 25 environments, [12] found that relative humidity was the primary climatic factor directly affecting grain yield in the rainforest of Southwest Nigeria. The study conducted by Adejuwon [13] also showed that high variation in rainfall significantly affected genotypic responses to the varying environments and concluded that variability in climate has wide impacts on maize yields in Southern part of Nigeria. Similar conclusions were reached by Oluwaranti *et al.* [14] in a study of effects of climatic factors on flowering traits of maize in the rainforest agroecological zone of Southwest Nigeria.

Table 6: Pearson correlation among the climatic factors and mean yield across environments

	MaxTemp	MinTemp	MeanTem	Heat Unit	Rainfall	RH(09Z)%	RH(15Z)%	Wspd(09Z)	Wspd(15Z)	Grain Yield
*MaxTemp										
MinTemp	0.368									
MeanTem	0.292	-.726**								
Heat Unit	-0.199	-0.245	0.388							
Rainfall	-.644**	-0.338	0.094	.713**						
RH(09Z)%	-.963**	-0.428	-0.174	0.252	.715**					
RH(15Z)%	-.905**	-0.397	-0.107	.488*	.881**	.934**				
Wspd(09Z)	-0.345	-0.176	0.089	.645**	.762**	0.391	.667**			
Wspd(15Z)	-.524*	-0.182	-0.152	0.042	.622**	.640**	.683**	.581**		
Mean Yield	-.498*	-0.236	0.012	.484*	.650**	.531*	.641**	.552**	.454*	

*See Table 5 for full meaning of acronyms/abbreviation

4. CONCLUSION

In conclusion, the total rainfall and minimum relative humidity accounted for the highest effect among the climatic factors affecting maize grain yield in rainforest agro-ecology of Nigeria. Also, the higher the amount of total rainfall and minimum relative humidity in rainforest agro-ecology of Nigeria, the higher the maize grain yield productions. Environments with the respective calendar dates; 24/04/2006, 24/04/2002, 01/05/2006, 17/04/2002, 10/04/2006 and 17/04/2006 in the early cropping season (Mid-April to very early May) in that order were the most favourable; and environments; 17/09/2001, 21/09/2005, 08/05/2006, 10/09/2001 and 03/04/2006 in this order were the unfavourable environments for maize production in a rainforest agro-ecology location of this study in Nigeria.

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