AMERICAN JOURNAL OF
ENVIRONMENT AND CLIMATE (AJEC)

ISSN: 2832-403X (ONLINE)

VOLUME 2 ISSUE 3 (2023)

PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Environment and Climate (AJEC)

Volume 2 Issue 3, Year 2023
ISSN: 2832-403X (Online)
DOI: https://doi.org/10.54536/ajec.v2i3.1846
https://journals.e-palli.com/home/index.php/ajec

Relationship between Climate Variables (Rainfall and Temperature) and Ginger Yield Across the Climate Belts of Nigeria

Okoye N. N.[1*], Nwagbara M. O.[2], Weli V. E.[3]

Article Information

Received: September 27, 2023

Accepted: October 30, 2023

Published: November 08 2023

Keywords

Climate Variables, Rainfal, Temperature, Ginger Yield, Climate Belts

ABSTRACT

Rainfall and temperature are very important elements and factors of weather and climate needed in the successful production of crops, including ginger. The relationship of these elements and ginger yield has not been given the due attention in Nigeria. Therefore, this study examined the relationship between Climate (Rainfall and Temperature) and Ginger Yield across the Climate Belts of Nigeria. Rainfall and Temperaturedata were obtained for the study from Nigerian Meteorological Agency (NiMet), Abuja while ginger yield data were collected from the experimental farms of National Root Crops Research Institute (NRCRI), Umudike, Agricultural Development Programme (ADP) and Nigerian Bureau of Statistics, Abuja. These data covered a period of 40 years (1980 -2019) and were analysed using simple linear regression, correlation and Analysis of Variance (ANOVA). Results obtained showed thatrainfall and temperature significantly predicted ginger yield across the four climate belts at $p<0.05$:Tropical Monsoon(TM) (F,12.0934)and jointly explained 45.2% of variation in ginger yield(r=.672and the R^2=.452);Tropical Savanna (TS)(F,17.3452)and jointly explained 35.6% of variation in ginger yield (r = .597 and R^2= .356);Warm Semi-Arid (WSA) (F,24.9501)and jointly explained 20.9% of variation in ginger yield (r= .457 and R^2= .209); and Warm Desert (WD)(F,29.8517) and jointly explained 30.1% of variation in ginger yield(r =.549 and R^2= .301).Based on these results, it is concluded here that there is a significant relationship between rainfall and temperature and ginger yields over the years and across the climate belts. The study recommends among others that planting and harvesting of ginger by farmers should align with the seasons as found in each of the four climate belts.

INTRODUCTION

Ginger (*Zingiber officinale Rosc.*), belonging to the Zingiberaceae family originated from Southeast Asia (Shuhaimi *et al.*, 2012) and has been cultivated for thousands of years for use as a spice and for herbal medicinal purposes (Akram *et al.*, 2011) is a commercially important herbaceous perennial plant, usually grown as an annual spice. It is extensively cultivated in the tropical to temperate climates of the world for its flavour, and pungency, and aromatic and healing characteristics associated with its essential oil and oleoresin contents (Srinivasan *et al.*, 2018). Ginger can be grown under both rainfed and irrigated conditions depending on the frequency and distribution of rainfall (Sharma & Sharma, 2012).The underground rhizomes are thick, hard and much branched, giving rise to primary, secondary and tertiary rhizomes. The mature roots of ginger are fibrous and the juice from old ginger roots is extremely potent and often used as spices and a quintessential ingredient of Chinese, Korea, Japanese and many South Asian cuisines for flavouring dishes (Jakes, 2007). It is also used largely as recipes such as ginger bread, cookies, crackers, cakes, ginger-ale and ginger beer. The medicinal values of these great ancient spices are widely recognized across the continents to contain a number of unique organic phytochemical ingredients that can take care of some human ailments. Recent studies on health related effects of ginger which have also stimulated farmers concern on the growth of the plant have shown the efficacy of the plant in some life challenging ailments such as entero-toxin induced diarrhoea, diabetic nephropathy, nausea, plasma antioxidant, vomiting, high cholesterol, high blood pressure and inflammation (Chen *et al.*, 2019; Ernest and Pittler, 2008; Kim *et al.*, 2010). The current major five exporting countries have been China, Nigeria, India, Jamaica, and Brazil Asumugha (2003). Nigeria is the fifth largest producer of ginger in the world (FAO, 2014) and the largest producer and exporter of ginger in Africa (FAO, 2008). Ginger is one of ten commodities identified by the United States of America International Department (USAID) and Nigerian Export Promotion Council (NEPC) in 2002 as having the greatest potential for creating increased economic growth, external and internal trade, opportunities for employment, and increased income and wealth for Nigerians (Sidi *et al.*, 2014). The cultivation of ginger in recent years especially in the rainforest zone of Nigeria is on the increase (Egbuchua and Enujeke, 2013).

For successful cultivation of the ginger, a moderate rainfall at the sowing time till the rhizomes sprout, fairly heavy and well-distributed showers during the growing period, and dry weather with a temperature of 28^0 to 35^0C for about a month before harvesting are necessary (Zaied & Zouabi, 2016; Garberof & Jäckering, 2021; Singh, *et al.*, 2022). Temperature above 35^0C and sunlight can result in leave scorch particularly in young plants on

[1] Agro-met Unit, National Root Crops Research Institute, Umudike, Abia State, Nigeria
[2] Department of Water Resources and Agrometeorology, Michael Okpara, University of Agriculture, Umudike, Abia State, Nigeria
[3] Department of Geography and Environmental management, University of Port Harcourt, Chuba, Uturu, Abia State, Nigeria
[*] Corresponding author's e-mail: nkimoore@yahoo.com

the other hand, low temperatures induce dormancy while high humidity throughout the crop period is necessary (Pavlova *et al.*, 2014, Byrnes & Bumb, 2017; Borras, *et al.*, 2022, Salnikov *et al.*, 2022; Karatayev *et al.*, 2022). In Nigeria, ginger is a crop mostly grown in Tropical Savanna climate belt with Kaduna State as the chief producer (Ayodele & Sambo, 2014). Although, in recent times with the increase in population growth and demand, ginger is now being produced in other climate belts of Nigeria particularly in the Tropical Monsoon (such as Abia, Anambra, Cross River, Delta and Imo States), Tropical Savanna which includes Kaduna and Nasarawa States, Warm Semi-arid (Sokoto and Zamfara) and Warm Desert Climate (Bernard 2008, Ayodele & Sambo, 2014).

In Nigeria, cultivation of crops is generally rain fed and with significant diurnal and seasonal variations in temperature thus making rainfall and temperature strong factors in crop production in the country. Rainfall does not start at the same time across the country and amounts also vary from the coast hinterland with the coastal areas receiving the highest while the extreme north receives the lowest. The success of ginger cultivation across Nigeria could be said to be largely dependent on rainfall and temperature, which are not only elements of weather and climate but also factors of climate. Despite this and the estimated magnitude of nutritional and potential economic importance of ginger farming in Nigeria, the impact of rainfall and temperature on the yields of ginger across the climate belts of Nigeria has not received the deserved attention.

MATERIALS AND METHODS

The study area is Nigeria and lies between longitudes 2° 49'E – 14° 37'E and latitudes 4° 16'N – 13° 52'N (Fig. 1). It is bounded on the North by the Republic of Niger, East by Cameroon and West by Benin Republic while the Southern boundary is Gulf of Guinea which is an arm of the Atlantic Ocean (Ofomata, 1975). Nigeria has four climate types following Koppen's Climate Classification. These climate types are distinguishable from the southern part of Nigeria to the northern part through north-central Nigeria. They are Tropical Monsoon climate (Am), Tropical Savanna climate (Aw), Warm Semi-Arid Climate (Bsh), and Warm Desert Climate (SWh) (but for easy identification of these climate belts in this study, they were recoded as TM, TS, WSA and WD respectively).

The Tropical monsoon climate has a very small temperature range. The temperature ranges are almost constant throughout the year. The southern part of Nigeria experiences heavy and abundant rainfall. These storms are usually convectional in nature due to the regions proximity, to the equatorial belt. The annual rainfall received in this region is very high, usually above the 2,000mm (78.7 in) rainfall totals giving for tropical rainforest climates worldwide. Over 4,000 m (157.5 in) of rainfall is received in the coastal region of Nigeria around the Niger delta area (Mmom, 2003).The Tropical Savannah Climate or Tropical Wet and Dry climate, is extensive in area and covers most of Western and north-central parts of Nigeria beginning from the Tropical Monsoon Climate boundary in Southern Nigeria to the Central part of Nigeria, where it exerts enormous influence on the region. This climate exhibits a well-marked rainy season and a dry season with a single peak known as the summer maximum due to its distance from the equator. Temperatures are above 18°C (64 °F) throughout the year (Obasi and Ikubuwaje, 2012). Rainfall total in Tropical Savanna Nigeria varies from 1,100 mm (43.3 in) in the lowlands of the river Niger Benue trough to over 2,000 mm (78.7 in) along the south western escarpment of the Jos Plateau (Okoh *et al.*, 2017). The Warm Semi-arid Climate or Tropical Dry climate is the predominant climate type in the northern part of Nigeria. Annual rainfall totals are lower compared to the

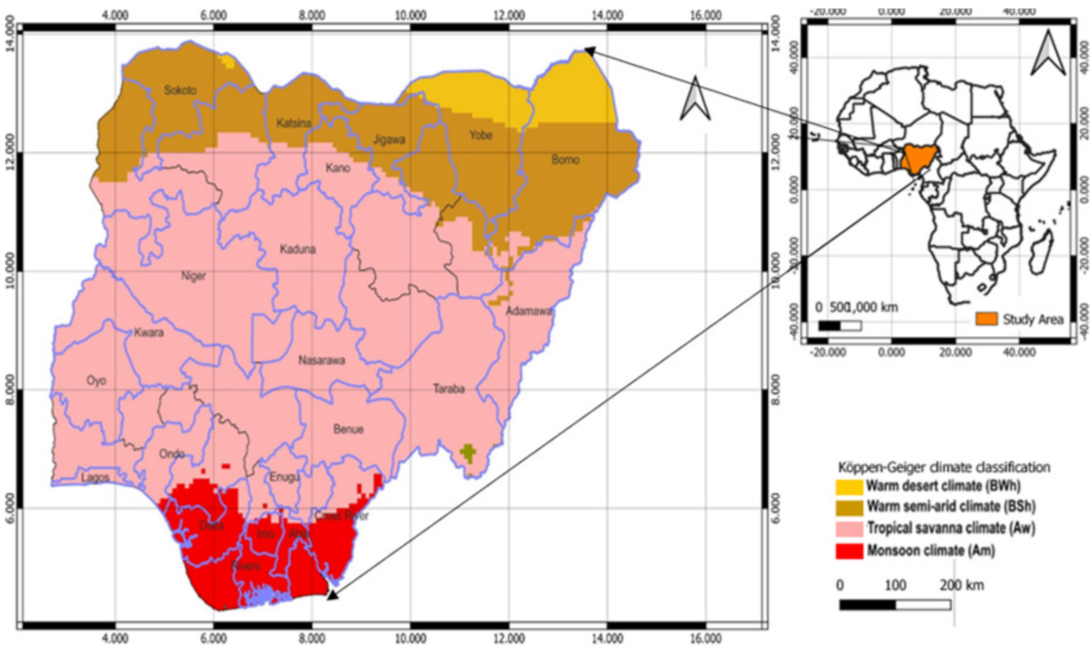

Figure 1: Map of Nigeria showing the Study Area (Tropical Monsoon Climate Belt)

Tropical Monsoon and Tropical Savanna belts of Nigeria. The rainy season in this belt last for only three to four months (June–September) while the rest of the year is hot and dry with temperatures climbing as high as 40°C (Okoh *et al*., 2011). Due to their location in the tropics, this elevation is high enough to reach the temperate climate line in the tropics thereby giving the highlands, mountains and the plateau regions standing above this height, a cool mountain climate (Oluwole and Ike, 2013). Nigeria is covered by three types of vegetation: forests (where there is significant tree cover), savannahs (insignificant tree cover, with grasses and flowers located between trees), and montane land. (The latter is the least common, and is mainly found in the mountains near the Cameroon border.) Both the forest zone and the savannah zone are divided into three parts. Some of the forest zone's most southerly portion, especially around the Niger River and Cross River deltas, is mangrove swamp. North of this is fresh water swamp, containing different vegetation from the salt water mangrove swamps, and north of that is rain forest (Olajuyigbe & Adaja, 2014).The Savannah zone's three categories are divided into Guinean forest-savanna mosaic, made up of plains of tall grass which are interrupted by trees, the most common across the country; Sudan savannah, similar but with shorter grasses and shorter trees; and Sahel savannah patches of grass and sand found in the Northeast (Mohammed, 2013).

The data used in this study included the primary and secondary data types. The secondary data are the climate data covering a period of 40 years from 1980 to 2019 included mean monthly maximum and minimum temperatures; and mean monthly rainfall were obtained from the office of Nigerian Meteorological Agency (NiMet), Abuja for this study, and data on ginger in tons per hectare were collected from the experimental farms of National Root Crops Research Institute (NRCRI), Umudike, Agricultural Development Programme (ADP) and Nigerian Bureau of Statistics, Abuja.. The study employed the use of Statistical Package for Social Sciences (SPSS) version 22. Simple linear regression and correlation were employed to explain the time series variations in meteorological parameters and ginger yield. The analysis of variance (ANOVA) was used because it has the capacity to determine the divergence in the mean of data, particularly, when the data sets are up to or more than three independent sets (Wahab & Jiao, 2020; Kumawat & Yadav, 2021).

RESULTS AND DISCUSSIONS

Table 1 shows the mean monthly distribution of rainfall amounts in the climate belts of Nigeria. During the study period, the month of January was wetter in the Tropical Monsoon (TM) Climate Belt with mean monthly rainfall of 33.5mm. The highest mean total rainfall amount of 348.4mm was recorded in the month of September whereas the lowest mean total rainfall amount of 33.1mm was recorded in the month of December. The month of July also recorded high amount of rainfall of 327.2mm followed by June that recorded 291.9mm mean amount of rainfall. There is rainfall in all the months of TM climate belt. The Warm Desert (WD) Climate Belt recorded the lowest amount of mean monthly rainfall. Its highest mean monthly rainfall of 202.1mm was in the month of August followed by the month of July which recorded 173.9mm amount of rainfall. The lowest amount of rainfall of 6.4mm was recorded in the month of April. The WD climate had total number of six months of rainfall which starts from the month of April and ends in the month of October. The WD climate recorded the highest number of months without rainfall (January, February, March, November and December). The mean monthly rainfall amount is higher than that of the Tropical Savanna (TS) Climate Belt which had a mean monthly rainfall for January as 9.3mm. In TS climate, the highest mean total amount of 265.5mm rainfall was recorded in the month of September as well whereas the lowest of 9.3mm of mean rainfall amount was recorded in the month of January. The month of July also recorded high amount of rainfall of 222.9mm, followed by June which recorded 210.4mm. TS climate had rainfall in all the months. The other two climate belts of Warm Semi-arid (WSA) Climate Belt and the Warm Desert Climate are exceptionally dry in the month of January with 0.2mm and 0mm of mean monthly rainfall respectively. The same pattern can be seen for February and March. Though, in April, the sign of wetness is witnessed in the Warm Desert Climate and a 6.4mm mean monthly rainfall is documented. For WSA climate, the highest mean monthly rainfall of 205.7mm was observed in the month of August and 179.4mm in the month of July while the lowest was 0.2mm in the month of January. However, the months of November and December recorded 0.0mm and 0.0mm respectively making it have total number of seven months of rainfall. Table 2 reveals the analysis of variance for differences in the seasonal amounts of rainfall in the study area. The

Table 1: Monthly Rainfall (mm) distribution across the climate belts of Nigeria (1980-2019)

Months	Tropical Monsoon Climate	Tropical Savanna	Warm Semi-arid Climate	Warm Desert Climate
January	33.5	9.3	0.2	0
February	54.8	20.8	0.3	0
March	126.4	55.2	1.8	0.3
April	186	113.7	7.9	6.4
May	248.6	175.2	52.2	30.9
June	291.9	210.4	82.5	75.3

July	327.2	222.9	179.4	173.9
August	282.8	203.8	205.7	202.1
September	348.4	265.5	108.5	102.7
October	277.3	167.4	20.4	13.2
November	103.5	27.3	0	0
December	33.1	11.2	0	0.1
Mean	**2313.7**	**1482.6**	**659**	**604.8**

seasons were the December January and February (DJF), March April and May (MAM), June July and August (JJA), then September October and November (SON). The essence here was to see if there have been differences in the patterns of rainfall within the seasons of the year. It is also critical to understand that whereas the second season (MAM) is critical for the planting, the third season (JJA) is majorly for growth and maturity of root and tuber crops in Nigeria, while the fourth (SON) and the first (DJF) seasons are critical for the harvest and storage of root and tuber crops in Nigeria in the Tropical Monsoon Climate. Similarly, the second season (MAM). For the Tropical Monsoon, all the seasons appeared to have been significantly different at $p<0.05$. The same can be said about the other climate belts of the country. This explains in clear terms that there have been significant changes in the seasonal rainfall amounts across the climate belts of the country over the past 40years (1980 – 2019). The temperature data presented in Figure 2 shows that in the Tropical Monsoon Climate Belt, temperature ranged from 25.6^{0}C in July to 27.5 in May. The months of June July August, appear cooler due to the effect of the rainy season in this belt at this period of the year. The Tropical Savanna Climate belt observed the highest temperature a little differently from the Tropical Monsoon Climates'. In this belt the highest temperature was encountered in the months of March and April, with 28.5^{0}C and 28.7^{0}C respectively. The coolest temperature was recorded in September with a mean monthly temperature of 26.1^{0}C. In the Warm Semi-arid Climate, April also recorded the highest temperature of 29.5^{0}C. The coldest month was the month of January with a temperature of 23^{0}C.

Table 2: Seasonal differences in rainfall in the climate belts

Tropical Monsoon						
Months	**Groups**	**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
DJF	Between	902365.12	3	157	7.1363	.006
	Within	813565.23	116	22		
MAM	Between	848565.13	3	144	13.0909	.001
	Within	712265.11	116	11		
JJA	Between	765165.13	3	163	11.6428	.003
	Within	622365.15	116	14		
SON	Between	635565.21	3	164	13.6666	.000
	Within	479765.11	116	12		
Tropical Savanna						
DJF	Between	772639.33	3	451	6.6323	.040
	Within	684730.31	116	68		
MAM	Between	580822.56	3	131	7.7058	.031
	Within	474914.16	116	17		
JJA	Between	259005.85	3	168	16.800	.000
	Within	164097.54	116	10		
SON	Between	147189.23	3	289	15.2105	.000
	Within	44280.22	116	19		
Warm Semi-arid Climate						
DJF	Between	880364.11	3	201	10.5789	.001
	Within	704455.45	116	19		
MAM	Between	557547.15	3	189	12.6000	.000
	Within	245638.24	116	15		
JJA	Between	644729.99	3	204	9.2727	.001
	Within	192178.99	116	22		

SON	Between	843564.12	3	228	17.5384	.000
	Within	563455.11	116	13		
Warm Desert Climate						
DJF	Between	868557.39	3	296	12.3333	.000
	Within	622659.45	116	24		
MAM	Between	730354.01	3	189	14.5384	.000
	Within	631255.7	116	13		
JJA	Between	606760.77	3	263	16.4375	.000
	Within	550862.47	116	16		
SON	Between	499464.16	3	223	10.6190	.001
	Within	239065.85	116	21		

DJF=December, January, February; MAM=May, June, July; JJA=June, July, August; SON=September, October, November

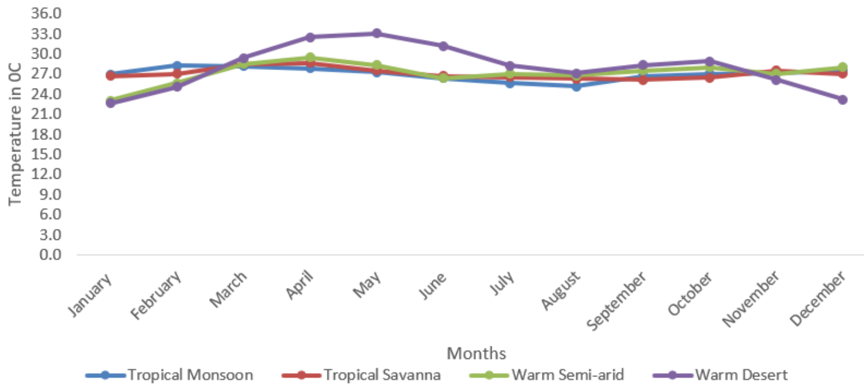

Figure 2: Mean monthly temperature distribution across the climate belts of Nigeria

The reason for the low temperature in January is the closeness of the region to the Sahara Desert and the cold tropical continental air mass which is more boisterous at that time of the year thereby affecting temperature of the area. This same condition applies to the Warm Desert Climate, which also had its coldest mean monthly temperature in the month of January (22.6^{0}C). Table 3 reveals the ANOVA computations for differences in the seasonal mean temperature in the study area. For the Tropical Monsoon, all the seasons appeared to have been significantly different at $p<0.05$. In the Tropical Savanna belt all the other seasons of the year were significantly different at $p<0.05$, but DJF was not significant at $p>0.05$. This could be possibly caused by the closeness of the

Table 3: Seasonal differences in temperature across the climate belts in Nigeria

Tropical Monsoon						
Months	**Groups**	**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
DJF	Between	900365.22	3	123	10.2500	.000
	Within	854565.2	116	12		
MAM	Between	808765.17	3	181	12.0667	.000
	Within	762965.15	116	15		
JJA	Between	717165.13	3	103	5.7222	.012
	Within	671365.10	116	18		
SON	Between	625565.08	3	134	6.3810	.010
	Within	579765.05	116	21		
Tropical Savanna						
DJF	Between	672639.08	3	89	1.4127	1.04
	Within	586730.77	116	63		
MAM	Between	500822.47	3	112	5.8947	.034
	Within	414914.16	116	19		
JJA	Between	329005.85	3	193	4.2889	.041
	Within	243097.54	116	45		

SON	Between	157189.23	3	123	7.2352	.020
	Within	71280.926	116	17		
Warm Semi-arid Climate						
DJF	Between	980364.23	3	108	9.8182	.000
	Within	744455.67	116	11		
MAM	Between	508547.11	3	192	2.4304	.231
	Within	272638.55	116	79		
JJA	Between	636729.99	3	134	9.5714	.003
	Within	199178.56	116	14		
SON		830564.006	3	117	7.8000	.005
		624455.698	116	15		
Warm Desert Climate						
DJF	Between	718557.39	3	161	1.6598	.067
	Within	662659.08	116	97		
MAM	Between	830354.01	3	110	5.0000	.001
	Within	774455.7	116	22		
JJA	Between	606760.77	3	143	3.7632	.051
	Within	550862.47	116	38		
SON	Between	494964.16	3	119	4.9583	0.041
	Within	439065.85	116	24		

DJF=December, January, February; MAM=May, June, July; JJA=June, July, August; SON=September, October, November.

region to the region where the tropical continental air mass prevails at the time of the year. In the Warm Semi-Arid Climate, it was MAM that was not significant at $p>0.05$. The other seasons of the year were significant at $p<0.05$. Finally, the Warm Desert Climate had all seasons of the year statistically significantly different at $p<0.05$ except DJF season that was not significant at $p>0.05$. Figure 3a reveals the time series plot for rainfall in the Tropical Monsoon Climate belt. The plot yielded a model with an R^2 0.6 and Y=1.85x + 2269.5. The model revealed a quasi-decadal pattern with no much noticed anomaly or deviation. Also, Figure 3b showed that there are some inherent anomalies in the rainfall distribution. Particularly, 1986 was exceptionaly dry and represented

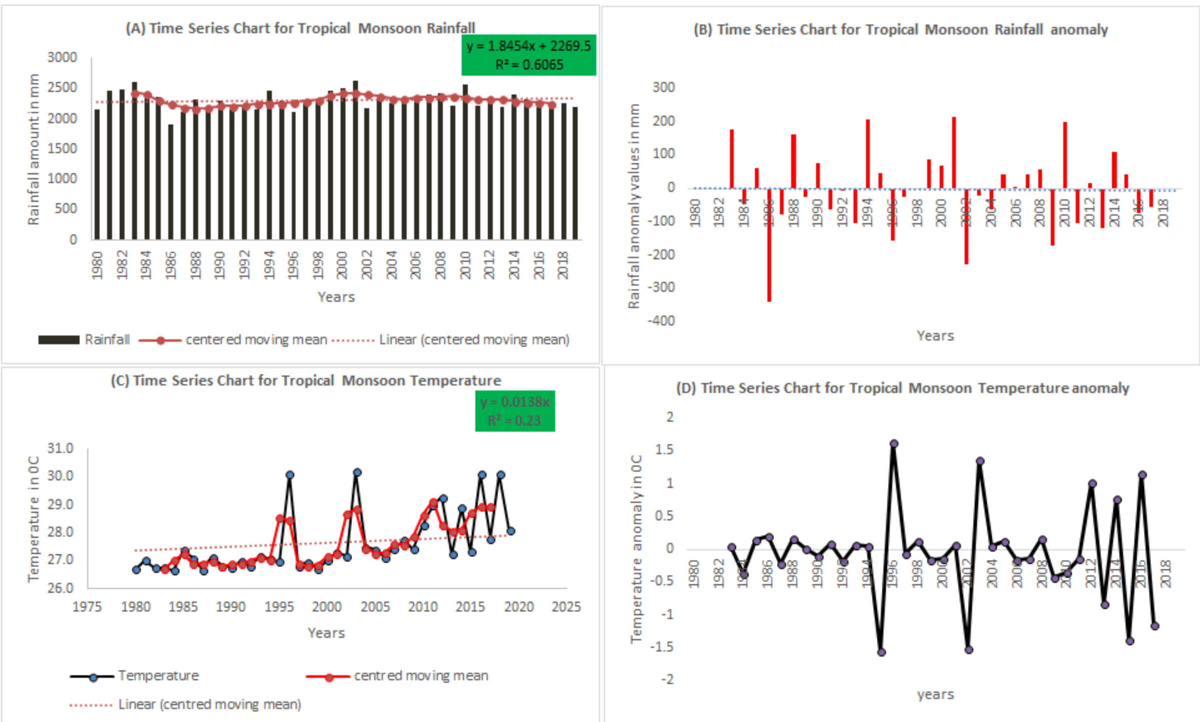

Figure 3: Rainfall and temperature time series and anomaly plots for the Tropical Monsoon Climate Belt.

the year with the driest rainfall with anormaly value of -350mm. In Figure 3c the temperature timeseries plot is presented. In the figure the temperature ranges between 26⁰C to 30.5⁰C. The temperature appeared to be on the increase contineously, although with some anomalies. There are two deviations within the continum, as seen in the year 1995 and 2004. In Figure 3d showed the anormalies in the temperature data, where 1995 and 2002 were very cool with the temperature anomalies of -1.5⁰C for each of them.

Figure 4a reveals the time series plot for rainfall in the Tropical Savanna Climate belt. The plot yielded a model with an R^2=0.046 and Y=58.15X. The model revealed a quasi-decadal pattern with no much anomaly or outliers. On the other hand, Figure 4b showed that there are some inherent anomalies in the rainfall distribution. Particularly, 1996 was abnormaly dry and represented the year with the driest rainfall with anormaly value of -45mm. In Figure 4c the temperature timeseries plot is presented. In the figure the temperature ranges between 26⁰C to 29.5⁰C. The temperature appeared to be on the increase contineously, although with some anomalies. There are two deviations within the continum, as seen in the year 2016 and 2018. In Figure 4d showed the anormalies in the temperature data, where 2013 and 2015 were very cool with the temperature anomalies of -0.13⁰C

Figure 4: Rainfall and Temperature time series and anomaly plots for the Tropical Savanna Climate Belt.

and 0.15⁰C respectively. Figure 5a reveals the time series plot for rainfall in the Warm Semi-arid Climate belt. The plot yielded a model with an R^2 0.7 and Y=35.05X. The model revealed a quasi-decadal pattern with two peaks while Figure 5b shows that there are some inherent anomalies in the rainfall distribution. Particularly, 1995 was abnormaly dry and represented the year with the driest rainfall with anormaly value of -48mm. In Figure 5c, the temperature timeseries plot is presented. In the figure the temperature ranges between 26⁰C to 28⁰C. The temperature appeared to be on the increase contineously, although with some anomalies. There is one peak within the continum, as seen in the year 2010. In figure 5d,it is shown that the anormalies in the temperature data, where 2010 was very cool with the temperature anomaly of - 0.15⁰C. Figure 6a reveals the time series plot for rainfall in the Warm Desert Climate belt. The plot yielded a model with an R^2 = 0.55 and Y=1.17x + 692.73. The model revealed a quasi-decadal pattern with two peaks. However, Figure 6b showed that there are some inherent anomalies in the rainfall distribution. Particularly, 2000 was abnormaly dry and represented the year with the driest rainfall with anormaly value of -212mm. In Figure 6c, the temperature timeseries plot is presented. In figure 6c, the temperature ranges between 26.5⁰C to 31.5⁰C. The temperature appeared to be on the increase continuously, although with some anomalies and a decade long consistent temperature distribution. There is three peaks within the continum, as seen in the years 1988 (30.5⁰C) 1997 (30.7⁰C) and 2017 (31⁰C). Figure 6d shows the anormalies in the temperature data, where 1997 was very hot with the temperature anomaly of 2.5⁰C. Most of the agricultural practices in the country are climate dependent. It is therefore possible to trace the yields of crops to the climate type of the place. It is also very common to use the amount and buoyancy of rainfall and temperature to measure these relationships. This is because these elements of weather and climate are pervasive and have controlling effects on other components of the environment. Table 4indicates the

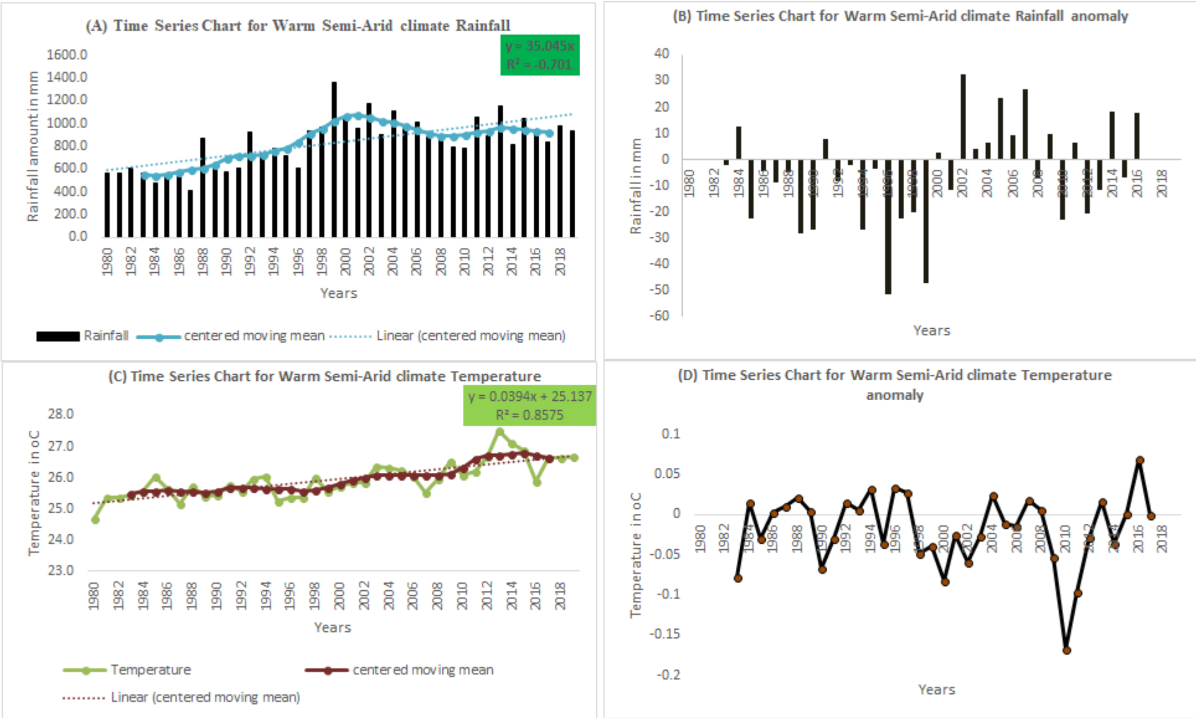

Figure 5: Rainfall and Temperature time series and anomaly plots for the Warm Semi-Arid Climate Belt.

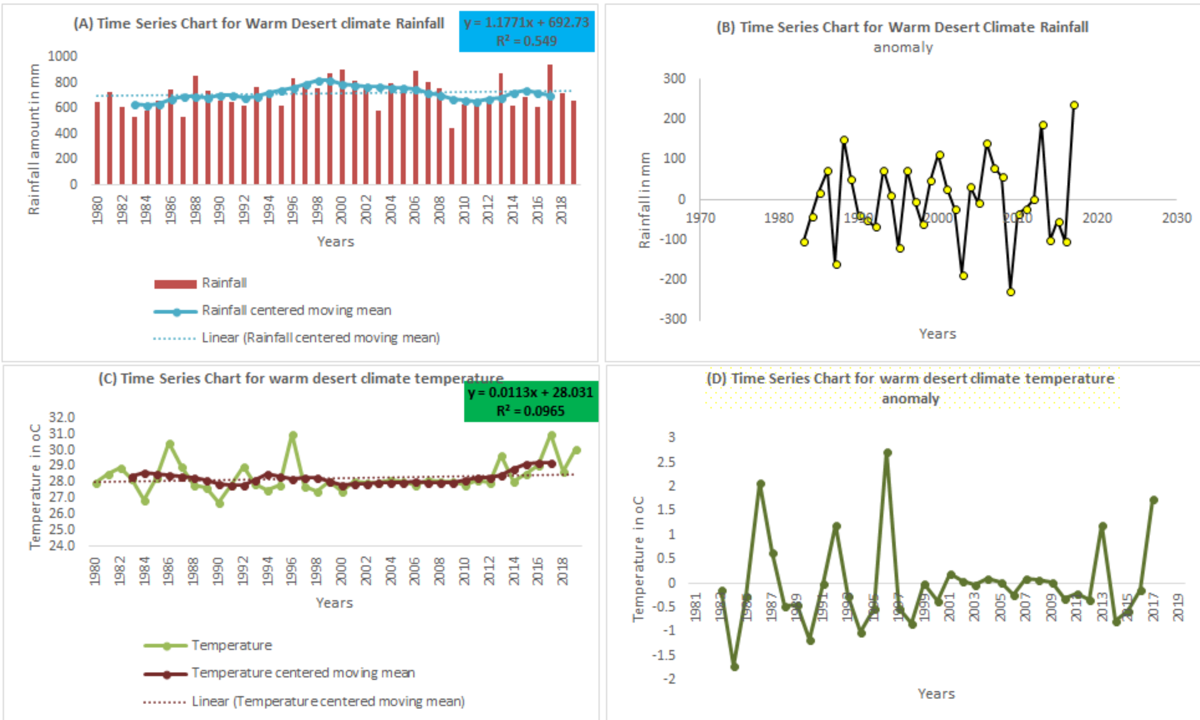

Figure 6: RRainfall and temperature time series and anomaly plots for the Warm Desert Climate Belt.

relationship between climate (rainfall and temperature) and the yields of ginger over the years. Here, the dependent variable (ginger) is regressed against rainfall and temperature (predictors). In the Tropical Monsoon Climate Belt, the rainfall and temperature significantly predicted ginger yield (F=12.0934; $p<0.05$) which indicates that temperature and rainfall play significant role in the yield of ginger in the Tropical Monsoon Climate Belt. The model revealed a positive relationship (r=0.672) and the R^2 was .452. This means that rainfall and temperature jointly explained 45.2% of variation in ginger yield in the Tropical Monsoon Belt of Nigeria.

In the Tropical Savanna Climate Belt, the rainfall and temperature significantly predicted ginger yield (F=17.3452; $p<0.05$) which indicates that temperature and rainfall play significant role in the yield of ginger in the Tropical Savanna Climate Belt. The model revealed a positive relationship (r=.597) and the R^2 was .356. This means that rainfall and temperature jointly explained 35.6% of variation in ginger yield in the Tropical Savanna Belt of Nigeria. In the Warm Semi-Arid Climate Belt, the rainfall and temperature significantly predicted ginger yield (F=24.9501; p<0.05) which indicates that temperature and rainfall play significant role in the yield of ginger in the Warm Semi-Arid Climate Belt (b1= R; .173 P<0.05, b2= T.343 P<0.05). The model revealed a positive relationship (r=.457) and the R^2 was .209. This means that rainfall and temperature jointly explained 20.9% of the variation in ginger yield in the Warm Semi-arid environment of Nigeria.

Table 4: The relationship between ginger yields and climate (rainfall and temperature) in the climate belts of Nigeria

Climate zone	Regression weights	N	Beta	R	R^2	F	P-value
TM	Rainfall, Temp→Ginger	40	.332	.672	.452	12.0934	0.004
			.423				
TS	Rainfall, Temp→Ginger	40	.354	.597	.356	17.3452	0.003
			.341				
WSA	Rainfall, Temp→Ginger	40	.173	.457	.209	24.9501	0.040
			.343				
WD	Rainfall, Temp→Ginger	40	.317	.549	.301	29.8517	0.002
			.281				

N:B: TM=Tropical Monsoon; TS=Tropical Savanna; WSA= Warm Semi-Arid Climate; WD=Warm Desert Climate.

In the Warm Desert Climate environment, rainfall and temperature significantly predicted ginger yield (F=29.8517; p<0.05) which implies that temperature and rainfall play significant role in the yield of ginger in the Warm Desert Climate environment. The model revealed a positive relationship (r=.549) and the R^2 was .301. This means that rainfall and temperature jointly explained 30.1% of variation in ginger yield in the Warm Desert Climate Belt of Nigeria.

Discussion of Findings

Climate, especially rainfall and temperature, is generally perceived to affect the growth, development and yield of crops in Nigeria (Agele & Bolarinwa, 2018). Annual, seasonal and monthly rainfall and temperature values have been seen from the results of the study that they vary with climate belt thus affecting the yields of ginger across the climate belts of Nigeria. The relatively low amounts of rainfall of WSA and WD Climate Belts as against TM and TS threatened the yield of ginger in the belts which call for irrigation if maximum yield is to be attained (Agele & Bolarinwa, 2018). This is corroborated by Zaied & Zouab, (2016), Garbero, & Jäckering (2021) and Singh, *et al.* (2022) who stated that successful production of ginger can be attained where a moderate rainfall at the sowing time till the rhizomes sprout, fairly heavy and well-distributed showers during the growing period, and dry weather with a temperature of 280 to 350C for about a month before harvesting are available. On the other hand, flooding and water-logging resulting from heavy rainfall and water stress such as drought resulting inadequate rainfall reduce the yields of root and tuber crops including ginger (Ayanlade, *et al.*, 2010). Generally, the identified climate events that affect ginger farming are extreme rainfall (TM & TS), Flooding (TM, TS & WSA) and drought conditions (TS, WSA & WD). This is in line with the work of (Nwachukwu *et al.*, 2012) who affirms that rainfall and temperature significantly affect agricultural production.

The assessment of the mean monthly temperature for the various climatic belts showed that there has been a difference in the monthly temperatures which ranged from 0.5^{0}C to 2.1^{0}C. In the TM Climate Belt, the months of October and April were hottest, while December was coolest. The coldness experienced in December in this belt was caused by the prevailing harmattan wind, which blows over the TM climate belt at this time of the year. The changes in the temperature hotness or coldness were traceable largely to the controls of the climate of Nigeria. And these include; but not limited to air masses (Tropical Maritime and Tropical Continental), elevation, rotation and revolution. On the anthropogenic side, urbanization, transportation, gas flaring, deforestation and the burning of bushes could be held accountable (Onwuka, 2012), as climate change becomes a topic of concern around the world (Hamisi & Abdillah, 2022: Amosah *et al.*, 2023). In the other belts that is, the TS, WSA and WD, the months of April, May and November were very critical as they stood out as the very hottest and erratic months of the year, when it came to temperature. This finding corroborated the finding of (Ayodele & Sambo, 2014).

The temperature ranged from 25.6 ^{0}C in July to 27.5 ^{0}C in May for the TM. The months of June July August, were cooler because of the rainy season in this belt at this period of the year. The Tropical Savanna Climate belt observed the highest temperature a little differently from the Tropical Monsoon Climates belt in which temperature ranged from 26.1^{0}C in December to 28.7^{0}Cin April. In the Warm Semi-Arid Climate Belt, April also recorded the highest temperature of 29.5 ^{0}C. The coldest month was the month of January with a temperature of 23^{0}C. The adducible reason for this low temperature in January is the closeness of the region to the Sahara Desert and the cold tropical continental air mass which is more boisterous at that time of the, year thereby affecting temperature of the area. This same condition applies to the Warm Desert Climate Belt, which also had its coldest mean monthly temperature in the month of January (22.6^{0}C). This finding is in line with (Onyeka, 2014), who argued that the Sahara Desert and the Atlantic Ocean play significant roles in the climatic outcomes of Nigeria. Whereas, the Atlantic Ocean provides a cooling effect to the south, the Sahara Desert play both cooling and heating effect to the north section of the country (Onwuka, 2012).In general, the temperatures across the climate belts are relatively good for the successful production of ginger as the temperatures are not above 35^{0}C to leave scorch particularly in young plants and also not low to the extent of inducing dormancy.The works of Byrnes & Bumb(2017); Borras, *et al.* (2022) and Salnikov *et al.*(2022) corroborate this assertion.

CONCLUSION

There is a significant relationship between rainfall and temperature and ginger yield from 1980 to 2019. Also, rainfall is more variable than temperature over the period studied and across the climate belts. Ginger is purely a product of the rainfall and temperature as observed, other climate variables and factors notwithstanding. This study recommended that climate smart agriculture should be encouraged. Planting and harvesting of ginger by farmers should align with the seasons as found in each of the four climate belts. Also, improvement in the agricultural practice and technology for farming is greatly needed. If Nigeria continues to rely on rainfall for ginger production without involving irrigation when the rains are gone will make the country not maximize the yield of the crop, and by extension reducing the economic benefits from ginger. Therefore, dams should be built by governments at all levels (Federal, State and Local Government Area) so as to encourage irrigation.

REFERENCES

Akram, A., Merunka, D. and Shakaib Akram, M. (2011). Perceived brand globalness in emerging markets and the moderating role of consumer ethnocentrism. *International Journal of Emerging Markets, 6*(4), 291-303. https://doi.org/10.1108/17468801111170329

Amosah J. Lukman T. & Nabomya E.D. (2023). Assessing Indigenous and Modern Adaptation Strategies to Climate Change among Legumes Producers in the Bongo District of the Upper East Region, Ghana. *American Journal of Environment and Climate, 2*(2), 1-14

Asumugha, G. N., Ayaegbunam, H. N., Ezulike, T. O., Nwosu, K. L. (2006). Guide to ginger production and marketing in Nigeria. National Root Crops Research Institute, Umudike Nigeria. *Ext. Guide 7*,1-7

Chen, G. T., Yuan, B., Wang, H. X., Qi, G. H. and Cheng, S. J. (2019). Characterization and antioxidant activity of polysaccharides obtained from ginger pomace using two different extraction processes. *International Journal of Biological Macromolecules, 139*, 801–809. https://doi.org/10.1016/ j.ijbiomac.2019.08.048

Egbuchua, C. N. & Enujeke, E. C. (2013). Growth and yield responses of ginger (Zingiber officinale) to three sources of organic manures in a typical rainforest zone, Nigeria. *J. Hortic. For., 5*(7), 109-114.

Ernest, E, Pittler, M. H. (2008). Efficacy of Ginger for nausea and vomiting: A systematic review of randomized clinical trial. *Br. J. Anesth. 84*(3), 367-371.

FAO (2008a). Soaring food prices: facts, perspectives, impacts and actions required. Document HLC/08/ INF/1 prepared for the High Level *Conference on World Food Security: The Challenges of Climate Change and Bioenergy, 3–5 June 2008, Rome*

FAOSTAT (2014). Production– Crops (2014) data. Food and Agriculture Organization of the United Nations. www.fao.org/faostat.

Garbero, A., & Jäckering, L. (2021). The potential of agricultural programs for improving food security: A multi-country perspective. *Global Food Security, 29,* 100529. https://doi.org/10.1016/j.gfs.2021.100529

Hamisi, S. H., & Abdillah, M. K. (2022). Role of Climate Change During the Covid-19 Pandemic. *American Journal of Environment and Climate, 1*(3), 12–16.

J. M., Woodley, C. M., Cech, Jr., J. J., and Hansen. L. J., (2004). Effects of global climate change on marine and estuarine fishes and fisheries. *Reviews in Fish Biology and Fisheries, 14*, 251-275.

Jakes J.S. (2007). Ginger as "Beverage of Champion". *J. Plant Nutr. 38*(6), 45-56.

Kim, J.S. and Kim, M.J. (2010). In vitro antioxidant activity of Lespedeza cuneata methanolic extracts.

Paavola, J. (2003). Livelihoods, Vulnerability and Adaptation to Climate Change in the Morogoro Region, Tanzania Centre for Social and Economic Research on the Global Environment, University of East Anglia, Norwich NR4 7TJ, UK Working Paper EDM Roessig,

Sharma M, Sharma R. (2011). Synergistic antifungal activity of Curcuma longa (turmeric) and Zingiber officinale (ginger) essential oils against dermatophyte infections. *J Essent Oil Bear Plants., 14(*1), 38–47. https://doi.org/10.1080/ 0972060X.2011.10643899.

Shuhaimi-O. M., Nadzifah, Y., Umirah, N. S., Ahmad, A. K. (2012). Toxicity of metals to tadpoles of common Sunda toad, Duttaphrynus melanostictus . *Toxicological and Environmental Chemistry. 94*(2), 364–376.

Singh, R. K., Joshi, P. K., Sinha, V. S. P., Kumar, M. (2022). Indicator Based Assessment of Food Security in SAARC Nations under the Influence of Climate Change Scenarios. *Future Foods,* 5100122.

Srinivasan, K. (2018). Ginger rhizomes (Zingiber officinale): A spice with multiple health beneficial potentials. *Pharma Nutrition,* 5(1), 18–28. https:// doi. org/10.1016/j.phanu.2017.01.001

Zaied, Y. B., & Zouabi, O. (2016). Impacts of climate change on Tunisian olive oil output. *Climatic Change, 139*(3–4), 535–549. https://doi. org/10.1007/ s10584-016-1801-3