Journal of Environment and Earth Science www.iiste.org
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.6, No.1, 2016

Effects of Agro-Climatic Variables on Yield of *Zea mays* L. in a Humid Tropical Rainforest Agroecosystem

Oroka Frank Oke
Department of Agronomy, Delta State University, Asaba Campus

ABSTRACT
Climate change is a major determinant of maize grain yield, hence understanding the climate-crop relationship. The study examine the relationship between maize yield and climate variables rainfall, relative humidity and temperature. The relationship between climatic variables and maize yield were determined using correlation analysis. The study found that total rainfall and maximum relative humidity showed positive correlation with yield while all temperature extremes showed negative relationship with yield. Maize crop planted in the months of April and September recorded the highest and least yield with values of 963.2kg/ha and 786.7kg/ha respectively. Total rainfall and mean relative humidity were positively correlated with grain yield at grain filling stage (61-100DAP) and whole cycle (1-100 DAP). The findings are relevant in planning appropriate adaptation innovations that can be used by farmers in maize production.
Keywords: Agro-climate, rainfall, temperature, relative humidity, maize yield, grain filling

INTRODUCTION

One of the significant threats to agricultural production in sub-Sahara Africa is climate. In Nigeria, crop production in the rainforest ecological zone is mainly rainfed and mostly dependent on nature. Crop farmers are generally exposed to variability in climate and risks associated with weather fluctuations. In the humid rainforest where it is believed that crops can be cultivated anytime, since the weather is favourable, limited field studies has been conducted to elucidate the climate relationship with crop growth. Under rainfed conditions, extreme climate variables such as maximum and minimum temperature, maximum and minimum relative humidity, rainfall, sunshine hours and potential evapotranspiration has been shown to influence crop yield (Adamgbe and Ujoh, 2013). Acquah and Kyei (2012) also noted that weather variability has great impact on crop yield variability. Hence an indepth knowledge of climate-crop interaction is necessary for sustainable intensification of crop production.

Date of planting, crop growth cycle, crop management practices and yield has been shown to be influenced by long term climate changes (Fakorede, 1985; Lansigan et al., 2000), while availability of moisture, potential evaporation and temperature are identified short-term weather fluctuations which affect maize growth and yield (Fakorede and Opeke, 1985; Omoyo et al., 2015). Research results reported by the Bergamaschi et al. (2004) and Berlato et al. (2005) have demonstrated the relationship between maize grain yield and agro-climate variables. The findings indicated that from anthesis to grain filling is the most critical period when the maize plant is very sensitive to water deficit. This is because maize plants tend to respond to high water demand during this critical period. The increased water demand during this period is associated with increased leaf area combined with high evapotranspiration associated with other physiological processes which contribute to grain yield such as number of cobs per plant and number of grains per cob.

Evaluating response of maize to agro-climatic variables can form a basis for providing adequate information to crop farmers which will enhance their capacity to adapt to variability in climatic conditions. The study is therefore aimed at determining the relationship between weather variables and maize yield, with specific reference to rainfall, temperature and relative humidity.

MATERIALS AND METHODS

The experimental site was a farmer's field at the outskirts of the Warri metropolis (latitude 5^0 31'N and longitude 5^0 45'E) in the humid rainforest agroecological zone of southern Nigeria. The area has a bimodal rainfall pattern, which forms the basis for early cropping (mid-March/April) and late season cropping (late August/early September) by farmers in the area. Maize was planted at six different planting dates in April, May, June, July, August and September 2012. All crops were planted at spacing of 90cm x 30cm and received NPK 15-15-15 at the rate of 200kg/ha. In each month of planting, plot size used was 10m by 3m ($30m^2$). Crops were harvested at maturity and yield of net plot obtained. Yield were converted to kg/ha. Meteorological data on rainfall, temperature and relative humidity were obtained from the Meteorological Centre Warri sub-station (Federal Ministry of Aviation). In other to reveal the degree of association between climatic variables and maize growth and yield, the data of the climatic variables were disintegrated into individual months and the data for those months representing each stage in the growth cycle were utilized for analysis. For the purpose of this study, growth cycle of maize was subdivided into as earlier described by Fakorede (2006):

- Early flowering (1-30 days after planting)

- Late vegetative to flowering (31-60 days after planting)
- Grain filling (61-100 days after planting)
- Whole cycle (1-100 days after planting)

The relationship between climatic variables and maize yield were determined using correlation analysis. Correlation matrix of climatic variables was also obtained.

Results and Discussion

Relationship between agro-climatic variables and yield of *Zea mays* are presented in Table 2. Total rainfall showed a non-significant positive correlation (r^2= 0.672) with yield. The higher the rainfall, the more the yield of the crop. The results of the study revealed that temperature generally showed a negative correlation with yield. These could be seen from the negative coefficients for maximum temperature (r^2= -0.328), minimum temperature (r^2= -0.147), and mean temperature (r^2= -0.761). This indicates that the higher the temperature the lower the yield of the maize crop and the lower the temperature the more the yield. In a related study, Joshi et al (2011) observed maize yield decline, with increase in temperature. Omoyo et al. (2015) reported negative correlation between maize grain yield and mean maximum temperature. Relative humidity (RH) generally showed positive correlation with yield as indicated in the highly significant maximum relative humidity (r^2=0.990) and mean relative humidity (r^2= 0.870), Omoyo et al. (2015) also observed that rising temperature and low relative humidity, a combination of which promotes field crop evapotranspiration, and the associated changes in inter-season rainfall tends to impact on seed germination, grain filling and length of growing season in maize.

Table 2: Correlation coefficients between agro-climatic variables and yield of *Zea mays*

Climatic variable	Correlation coefficient
Total rainfall	0.672
Maximum temperature	-0.328
Minimum temperature	-0.147
Mean temperature	-0.761
Maximum relative humidity	0.990**
Minimum relative humidity	0.666
Mean relative humidity	0.870**

**significant at 0.01 level of probability

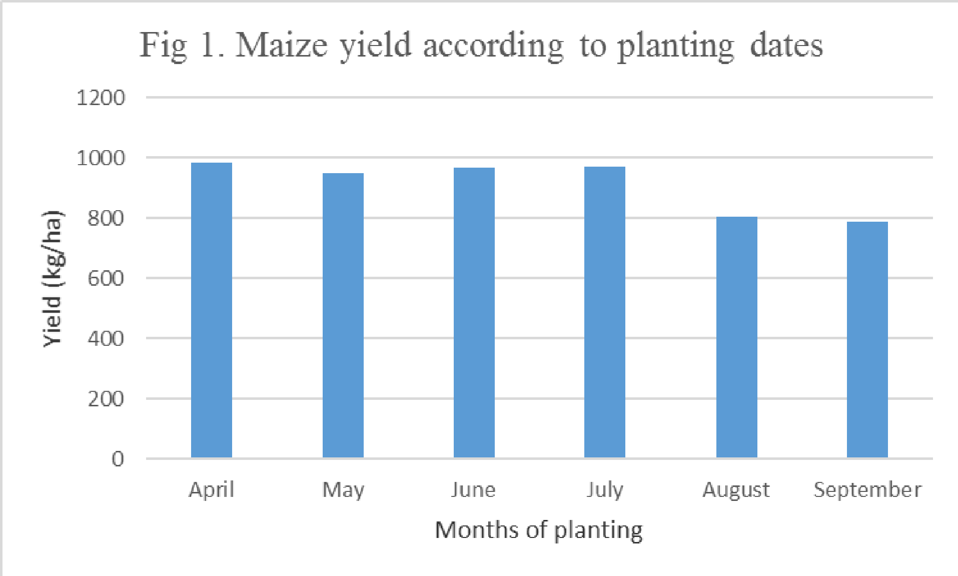
Results obtained from the correlation matrix of climatic variables indicated that total rainfall (TRF) showed a positive relationship with maximum relative humidity, minimum relative humidity, and mean relative humidity. However the reverse was the case with temperature, which indicated negative correlation with rainfall. Increase in total rainfall significantly reduced mean temperature (r^2= -0.864). As expected increase in maximum temperature resulted in reduction in maximum relative humidity (r^2= -0.418), minimum relative humidity (r^2= -0.736), and mean relative humidity (r^2= -0.703). Increase in minimum temperature and mean temperature also decreased relative humidity, with highly significant negative coefficients in minimum relative humidity (r^2= -0.925) and mean relative humidity (r^2= -0.970). This indicates that significant decline in mean relative humidity was associated with increase in mean temperature.

Table 2. Correlation matrix of agro-climatic variables

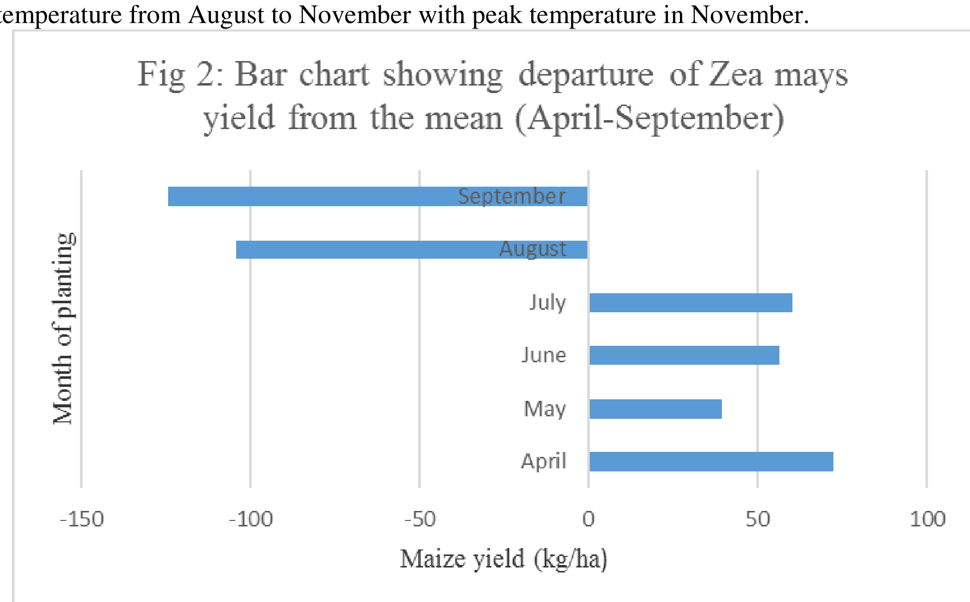
	TRF	$Temp_{max}$	$Temp_{min}$	$Temp_{mean}$	RH_{max}	RH_{min}	RH_{mean}
TRF	-	-0.480	-0.701	-0.864*	0.699	0.745	0.811
$Temp_{max}$		-	0.696	0.799	-0.418	-0.736	-0.703
$Temp_{min}$			-	0.657	-0.226	-0.450	-0.517
$Temp_{mean}$				-	-0778	-0.925**	-0.970**
RH_{max}					-	0.655	0.891*
RH_{min}						-	0.898*
RH_{mean}							-

*significant at 0.05 level of probability; **significant at 0.01 level of probability

TRF- total rainfall; $Temp_{max}$ - maximum temperature; $Temp_{min}$ – minimum temperature;
RH_{max}- maximum relative humidity; RH_{min}- minimum relative humidity; RH_{mean}- mean relative humidity



Maize crop planted in the months of April and September recorded the highest and least yield with values of 963.2kg/ha and 786.7kg/ha respectively (Figure 1). While the April planting coincided with early season cropping of farmers, the September planting was done in the late season. Deviation of maize yield from the mean at the various planting dates is shown in Figure 2. The month of May had the lowest positive deviation with value of 39.4, while the first planting in April showed the highest deviation (72.4). Negative deviation was observed when maize was planted in August (-104.2) and September (-124.2). The August/September planting coincided with late season cropping with critical development phases such as anthesis and grain filling occurring in period with relatively lower total rainfall, low mean relative humidity and higher mean temperature. Fakorede (2006) observed that one of the factor negatively affecting maize yield in the rainforest agroecosystem is the increased temperature from August to November with peak temperature in November.



At the early vegetative growth (1-30DAP) and late vegetative to flowering stage (31-60DAP), total rainfall showed a negative correlation with grain yield (Table 3). This shows that lack of sufficient rainfall during this stages of growth may not adversely affect crop yield. Shaw (1977) and Fakorede (2006) reported that much moisture is not required at the early vegetative growth of maize, however lack of moisture at two weeks before to two weeks after flowering can significantly reduce maize grain yield. Significant positive correlation with total rainfall was only observed at grain-filling stage (r^2= 0.902). A positive correlation between grain yield and total rainfall was observed for the whole cycle (1-100 DAP), that is the higher the rainfall during the whole cycle of the maize crop the higher the yield. Earlier reports by other researchers (Glantz, 1994; Ribot et al., 1996; Odeyemi and Ogunkoya, 2006) have shown that crop germination and yield are greatly determined by various rainfall conditions such as peak of rain, false start of rainfall and retreat of rainfall.

Table 3. Correlation coefficients between agro-climatic variables and grain yield at different growth stages of *Zea mays*

	Early vegetative growth (1-30 DAP)	Late vegetative to flowering (31-60 DAP)	Grain filling (61-100 DAP)	Whole cycle (1-100 DAP)
Total rainfall	-0.320	-0.058	0.902*	0.672
Mean temperature	0.381	-0.528	-0.687	-0.776
Mean relative humidity	-0.401	-0.163	0.942**	0.739

*significant at 0.05 level of probability; **significant at 0.01 level of probability

Except the early vegetative growth stage which showed a moderate positive correlation between mean temperature and grain yield, the other stages, which include late vegetative to flowering (r^2= -0.528), grain filling (r^2= -0.687) and whole cycle (r^2= -0.776) indicated negative correlation with yield. Hence increased mean temperature at these stages was detrimental to grain yield.

Negative correlation was observed between mean relative humidity and maize yield at early vegetative growth stage ((r^2= -0.401) and late vegetative to flowering stage (r^2= -0.163), an indication that within the first 60 days of the growth cycle, increase in mean relative humidity resulted in decline in grain yield. At the grain filling stage a highly significant positive correlation (r^2= 0.942) was observed between mean relative humidity and grain yield. Positive correlation (r^2= 0.739) between grain yield and mean relative humidity was also observed on the whole cycle. In other words, impact of high mean relative humidity was detrimental to grain yield at early vegetative stage and late vegetative to flowering stage, while it contributed to grain yield increase at the grain filling stage and the whole cycle.

Conclusion

Based the results, it can be concluded that climatic variability affects maize growth and yield in the study area, which is a typical rainforest agroecology. The findings are relevant in planning appropriate adaptation innovations that can be used by farmers in maize production

References

Acquah, H.D and Kyei, C. K. (2012) The effects of climatic variables and crop area On maize yield and variability in Ghana Russian Journal of Agricultural and Socio-Economic Sciences 10 (10): 10-13

Adamgbe, E.M. and Ujoh F. (2013) Effect of variability in rainfall characteristics on maize yield in Gboko. Nigeria J Environ Prot. 4:881–887

Bergamaschi H, Dalmago G.A., Bergonci, J.I., Bianchi, C.A.M., Müller, A.G., Comiran F, et al. (2004) Water supply in the critical period of maize and the grain production. Pesq Agrop Brasileira.39 (9):831–839.

Berlato, M.A., Farenzena H, Fontana, D.C. (2005) Association between El Niño Southern Oscillation and corn yield in Rio Grande do Sul State. Pesq Agrop Brasileira. 40:423–432

Fakorede, M.A.B. (1985) Response of maize to planting dates in a tropical rainforest location Expl. Agric. 21:19-30

Fakorede, M.A.B and Opeke, B.O. (1985) Weather factors affecting the response of maize planting dates in a tropical rainforest location Expl. Agric. 21: 31-40

Fakorede, M.A.B. (2006) The effects of climatic factors on maize yield in the rainforest zone in southwestern Nigeria p. 181-188 In J.O.Adejuwon and O.O. Ogunkoya (eds) Climate change and food security in Nigeria. Ile Ife: Obafemi Awolowo University Press

Glantz, H.M. (ed) (1994) Drought, Desertification and Food Production: In Drought, Follows the Plow: Cultivation of Marginal Areas. Cambridge: Cambridge University Press

Joshi, N. P.; Maharjan, K.L. & Piya L. (2011) Effect of Climate Variables on Yield of Major Food-crops in Nepal A Time-series Analysis Journal of Contemporary India Studies: Space and Society 1:19-26

Lansigan, F.P., de los Santos, W.I. and J.O. Coladilla (2000) Agronomic impacts of climate variability on rice production in the Philippines Agriculture, Ecosystems and Environment 82: 129-137

Odeyemi, Y.A. and Ogunkoya O.O. (2006) Climate variability and crop yield in guinea savanna p. 169-180 In J.O.Adejuwon and O.O. Ogunkoya (eds) Climate change and food security in Nigeria. Ile Ife: Obafemi Awolowo University Press

Omoyo, N.N.; Wakhungu, J. and Oteng'i, S. (2015) Effects of climate variability on maize yield in the arid and semi arid lands of lower eastern Kenya Agriculture & Food Security 4(8):1-13

Ribot, J.C., Magalhaes, A.R. and S. Panagides (1996) Climate variability, climate change and social vulnerability in the semi-arid Tropics. Cambridge: Harvard University. www.enda.com

Shaw, R.H. (1977) Climate requirements p. 591-623. In G.F. Sprague (ed.): Corn and corn improvement, 2nd ediion. Madison, Wisconsin USA. America Society of Agronomy.